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An Investigation of Pricing Models for Live Cattle and Feeder Cattle Options

by

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Abstract

This study investigated the performance of Black's European model and Barone-Adesi and Whaley's American model in pricing live cattle and feeder cattle futures options. One historical and three implied volatility estimators were employed. The live cattle sample period was October 31, 1984 through September 30, 1988. The feeder cattle sample period was January 4, 1988 through September 30, 1988. One observation per day was collected for all put and call contracts and all strike prices. Contemporaneous futures prices were collected to match the put and call observations.

Black's European model was as accurate in predicting premiums as Barone-Adesi and Whaley's American model across all volatility estimates and option contracts. Implied volatility estimates generated substantially more accurate forecasts of actual option premia than historical volatility. Small differences were found in the predictive ability among the three implied volatility estimates.

The significance and signs of the coefficients and explanatory power of the bias regressions were generally consistent across both option pricing models, suggesting that little difference in biases existed between the American and European model. Generally, fewer coefficients were significant in the implied volatility equations compared to the historical volatility equations. In addition, the magnitude of bias associated with variables in the implied volatility equations was substantially less than that of variables in historical volatility equations. Finally, it was found that none of the variables input into the option pricing models (time-to-maturity, moneyness, volatility, and the riskless interest rate) displayed consistently significant coefficients across markets and option type.

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I. INTRODUCTION

Commodity options developed simultaneously with commodity futures contracts in the mid-1800s, but options were banned in 1936.[1] Options on futures contracts were re-introduced in 1982, providing hedgers and speculators an alternative to traditional futures and forward contracts for managing price risk.

Both call and put options are traded. A call option contract gives the owner the right, but not the obligation, to buy a fixed number of units of an underlying security for a fixed price at any time on or before a given date. Conversely, a put option contract gives the owner the right, but not the obligation, to sell a fixed number of units of an underlying security for a fixed price at any time on or before a given date. These rights provide options buyers protection against adverse price changes while maintaining the possibility of benefiting from favorable price changes. For example, a producer can establish a price floor but benefit from subsequent price increases by purchasing a put option. Conversely, a processor can establish a price ceiling but benefit from subsequent price declines by purchasing a call option. In contrast to options, buying or selling a futures contract establishes a fixed price, because, assuming no basis risk, cash market gains or losses are offset by futures market gains or losses.

The asymmetric price protection offered by options is not gained without a cost. The option buyer must compensate the option seller for accepting a risky position of limited profits and unlimited losses. The compensation is the option's value, or premium, and is determined in a competitive marketplace. By accepting the premium, the option seller must perform according to the terms of the option contract.

Option Pricing Models

Black and Scholes (1973) derived the first exact closed-form option pricing model for securities options. It was based on arbitrage arguments and the law of one price. Black (1976) modified the original Black and Scholes model to price options on futures contracts. Both models are a function of five observable variables: 1) the price of the underlying security, 2) the time to maturity of the option, 3) the riskless interest rate, 4) the strike price of the option, and 5) the volatility of the returns on the underlying security. Market participants use the Black and Scholes and Black models extensively as a benchmark for evaluating actual market premia (Jarrow and Rudd, 1983).

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[1]See Hoag (1983) for a complete review of the history of commodity options.

Black's model applies only to options that can be exercised only at expiration (a European option). However, options traded on U.S. exchanges generally can be exercised on or before expiration (an American option). This early exercise feature provides additional flexibility, which may be economically valuable. As a result, Black's model may produce systematic pricing biases because it cannot value the early exercise feature.

To date, a closed-form model for valuing American futures options has not been derived. However, a number of models have been proposed based on approximation techniques. A computationally efficient model was recently developed by Barone-Adesi and Whaley (1987). Their model assumes that a futures price exists such that investors are indifferent to the feature of early exercise. Intuitively, their model calculates call (put) values as: 1) the value of Black's model plus an early exercise premium if the critical futures price is greater (less) than the current futures price, or 2) the option's immediate exercise value if the critical futures price is less (greater) than the current futures price.

Purpose of Present Study

Several studies have investigated the performance of futures options pricing models. However, a limited number have used contemporaneous futures and options data (Shastri and Tandon, 1986a, 1986b; Whaley, 1986; Jordan, Seale, McCabe, and Kenyon, 1987; Followill, 1987). Only one study (Shastri and Tandon, 1986a) has compared the pricing accuracy of the Black model and an American model. Since this study examined S&P 500 and German Mark options, no evidence exists on the issue for commodity futures options. The present study will compare the performance of Black's European model and Barone-Adesi and Whaley's American model in pricing live cattle and feeder cattle futures options.

Live cattle and feeder cattle options were selected for two reasons. First, no published study has investigated the performance of models in pricing livestock futures options. Second, the volume of live cattle and feeder cattle futures options has increased rapidly since trading began in October 1984 and January 1987, respectively. In early 1988, the volume of options on both commodities had risen to approximately 30 percent of the underlying futures volume (Pelly, 1989). The increase in volume suggests that live cattle and feeder cattle options have become important risk management instruments. Hence, an investigation of the performance of options pricing models will be useful to traders, market regulators, and academic researchers.

Since it is well-documented (e.g. Hauser and Neff, 1985) that options pricing model values are highly sensitive to changes in the volatility of futures prices, different volatility estimators should be employed in tests of model performance. One historical and three implied volatility estimators will be used in this study. The historical volatility estimator is based on historical prices for the underlying futures contract. The implied volatility estimators use numerical procedures to iteratively deduce a volatility estimate from the realized market premium.

The performance of each option pricing model and volatility estimator will be investigated utilizing accuracy and bias tests. The accuracy test will examine the deviations between the actual market price and the model price. The bias tests will relate these deviations to the exogenous variables of the options pricing models and contract and seasonal dummy variables.

II. FUTURES OPTIONS PRICING: THEORY AND EVIDENCE

The Black and Scholes Model

Black and Scholes (1973) provided the seminal breakthrough in modern option pricing theory. They derived a valuation formula for securities options that is a closed-form equilibrium pricing model. Black and Scholes argued that a continuously adjusted hedge portfolio, acquired by combining appropriate positions in the underlying security and an option, was riskless over small time intervals.[2] Therefore, profits (losses) due to movements in the price of the underlying security could be exactly offset by losses (profits) in the options position. The absence of riskless arbitrage opportunities assures that in equilibrium all risk-free investments yield the risk-free rate of return. Thus, the hedge portfolio should also yield the risk-free rate of return. Black and Scholes' fundamental insight was that an option's price is implied by such a hedged portfolio.

The Black and Scholes model for pricing call options on securities is,

$$c = SN(d_1) - Xe^{-rT}N(d_2) \tag{1}$$

where

c = equilibrium market value of a call option on a security,

S = price of the underlying security,

T = time to expiration of the option contract,

X = strike price,

r = risk-free rate of interest,

σ^2 = variance of the price changes of the underlying security,

$d_1 = [\ \ln(S/X) + (r + \sigma^2/2)T\ ]/\sigma\sqrt{T}$,

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[2]The relative size of securities and options positions is determined by the hedge ratio, which is the ratio showing the change in the value of the option position for a one unit change in the price of the underlying security.

$$d_2 = d_1 - \sigma\sqrt{T} = [\ \ln(S/X) + (r - \sigma^2/2)T\ ]/\sigma\sqrt{T},$$

N(.) = normal cumulative density function.

In contrast to prior option pricing models (Boness, 1964; Samuelson, 1967; Samuelson and Merton, 1969), the Black and Scholes model does not include unobservable parameters such as the expected value of the stock price at maturity, the expected return on the stock, or the shape of the investor's utility curve.

The assumptions underlying the derivation of the Black and Scholes model should be noted. They are:

(1) the risk-free rate of interest is a known constant throughout the life of the option contract,

(2) investors can borrow or lend unlimited amounts at the risk-free rate of interest,

(3) asset markets are frictionless, e.g., there are no taxes, transaction costs, etc.

(4) the price of the underlying security is continuous, lognormally distributed, and follows a random walk diffusion process,

$$dS/S = \mu dt + \sigma dz \tag{2}$$

where
μ = the mean rate of return of the security,

dt = a one unit change in time,

and
dz is a Gauss-Wiener process,

(5) the variance of price changes is known and constant over time,

(6) the option is European,

(7) there are no penalties for short sales, and

(8) there are no dividends.

Black (1976) later modified the Black and Scholes model to price options on futures contracts. He argued that since there is no initial cash outlay or investment required to assume a futures position, the value of the contract at time t is zero. Since the initial "good faith" margin may be in the form of an interest bearing asset, there is no opportunity cost when initiating a futures position. This assumption precludes the inclusion of the interest rate in the calculation of the d_1 and d_2 terms of the Black and Scholes model.

Therefore, Black's model for pricing calls on futures options (BOPM) is:

$$c = e^{-rT}[fN(d_1) - XN(d_2)] \tag{3}$$

where

c = equilibrium market value of a European call option on a futures contract,

f = underlying futures price,

$d_1 = [\ln(f/X) + (\sigma^2/2)T]/\sigma\sqrt{T}$,

$d_2 = d_1 - \sigma\sqrt{T} = [\ln(f/X) - (\sigma^2/2)T]/\sigma\sqrt{T}$,

and all other variables are as defined for equation (1).

Substituting (3) into the put-call parity relationship for European futures options (Stoll, 1969) and noting $N(-d) = 1 - N(d)$ yields Black's put option pricing formula:

$$p = e^{-rT} [XN(-d_2) - fN(-d_1)] \tag{4}$$

where

p = equilibrium market value of a European put option on a futures option,

and all other variables are as defined for equation (3).

The Barone-Adesi and Whaley Model

The BOPM was derived assuming the option can be exercised only at expiration (European-type). However, options traded on regulated U.S. exchanges are American options that can be exercised on or before their expiration. The potential value of the early exercise privilege can be seen by examining equation (3). As f becomes extremely large relative to X, $N(d_1)$ and $N(d_2)$ approach one and the value of a European call option approaches $(f-X)e^{-rT}$. An American option may be exercised immediately for $(f-X)$ which is greater than $(f-X)e^{-rT}$. Hence, for certain values of f, the call option is worth more "dead" than "alive". Similar arguments can be made for put options on futures contracts.

To date, a closed-form model for valuing American futures options has not been derived. A number of models have been proposed based on approximation techniques. A computationally efficient model was recently developed by Barone-Adesi and Whaley (1987). Their model assumes that a value of f, F^*, exists such that investors are indifferent to the feature of early exercise. Intuitively, their model calculates call (put) values as the value of Black's model plus an early exercise premium if $f < F^*$ ($f > F^*$) or the option's intrinsic value if $f \geq F^*$ ($f \leq F^*$). The Barone-Adesi and Whaley model (BAWOPM) for pricing an American call option is formally defined as follows:

$$C = c + A_2(f/F^*)^{q2} \qquad \text{when } f < F^* \tag{5}$$

$$C = f - X \qquad \text{when } f \geq F^* \tag{6}$$

where

C = value of an American call option on a commodity futures contract,

c = BOPM value as defined in equation (3),

$A_2 = (F^*/q_2)\{1 - e^{-rT}N[d_1(F^*)]\}$,

$d_1(F^*) = [\ln(F^*/X) + .5\sigma^2T]/\sigma\surd T$,

$q_2 = [1 + \surd(1 + 4k)]/2$,

$k = 2r/[\sigma^2(1 - e^{-rT})]$.

F^* is the critical futures price above which one would immediately exercise the American call option. It can be solved according to the iterative process of Barone-Adesi and Whaley using the formula,

$$F^* - X = c^* + \{1 + e^{-rT}N[d_1(F^*)]\}F^*/q_2 \tag{7}$$

Note that c^* is the BOPM evaluated at F^*.

The approximation for an American put is,

$$P = p + A_1(f/F^{**})^{q1} \qquad \text{when } f > F^{**} \tag{8}$$

$$P = X - f \qquad \text{when } f \leq F^{**} \tag{9}$$

where

P = value of an American put option on a futures contract,

p = BOPM value as defined in equation (4),

$A_1 = -(F^{**}/q_1)\{1 - e^{-rT}N[-d_1(F^{**})]\}$,

$q_1 = [1 - \surd(1 + 4k)]/2$,

and all other notation is the same as above for the valuation of the American call. The iterative formula for determining F^{**} is,

$$X - F^{**} = p^{**} - \{1 - e^{-rT}N[-d_1(F^{**})]\}F^{**}/q_1 \tag{10}$$

Note that p^{**} is the BOPM evaluated at F^{**}.

Empirical Testing Procedures

Three tests have been employed to evaluate the performance of option pricing models: (1) accuracy tests, (2) bias tests, and (3) efficiency tests. Accuracy tests are based on the deviations between corresponding market and model prices. The deviations are typically calculated as,

$$CD = C_{mkt} - C_{model} \tag{11}$$

$$PD = P_{mkt} - P_{model} \tag{12}$$

where C and D signify, respectively, call and put premiums. Summary statistics on the difference series provide information about the overall accuracy of premiums predicted by a model.

Bias tests are used to determine the systematic factors related to model mis-pricing. The difference series between market and model prices is regressed on exogenous variables. If a statistically significant parameter estimate is found, a source of systematic bias has been identified. A statistically significant constant term indicates that omitted sources of systematic biases exist.

Efficiency tests are used to determine if a model can be a basis for strategies that earn riskless profits. In an efficient market, a riskless hedge will not produce a return greater than the riskless rate. Hence, the null hypothesis of market efficiency is tested using an _ex post_ hedging strategy. To initiate the hedging strategy, "over-valued" and "under-valued" options are identified. "Over-valued" options have a market price greater than the model price. Conversely, "under-valued" options have a market price less than the model price. Next, riskless portfolios of "over-valued" and "under-valued" options and corresponding long and short positions in the underlying security are constructed. The number of options bought or sold for each unit of the underlying security is the reciprocal of the hedge ratio. Subsequently, the hedged portfolios are liquidated at some predetermined point in time and the rates of return are calculated. If the risk adjusted returns from the hedged portfolio (net of all costs) exceed the amount that could have been earned by investing in a risk free bond, the null hypothesis is rejected and the market is termed inefficient with respect to the option model evaluated.

Efficiency tests should be viewed with caution. Phillips and Smith (1980) argued that efficiency studies had not fully accounted for transactions costs, which should include commissions and other explicit fees, market liquidity costs, and the implicit costs of information collection. They found that when such a full accounting of costs was applied to the hedging returns generated in several studies, the excess returns were generally eliminated. Another problem confronted in efficiency studies is the altering of positions to maintain a truly riskless hedge. Conceptually, the hedges should be adjusted continuously. Since this cannot be accomplished in practice, it is uncertain whether hedging profits above the riskless rate are abnormal returns or returns to risk. If the hedging returns are argued to be a return to risk, then the correct model for adjusting for risk is a subject of debate. The Capital Asset Pricing Model has been severely criticized (Roll, 1977) and the Arbitrage Pricing Model (Ross, 1976) has yet to gain general acceptance as an equilibrium model of asset pricing.

Two issues are critical in all empirical tests of options pricing models. The first is the matching of contemporaneous market prices for the option and underlying futures contract. Non-contemporaneous data may lead to incorrect results because the price of the underlying security incorporated into the option pricing model is not the price upon which the option was written (Bookstaber, 1981). This problem may be substantial when daily closing or settlement prices are used. For example, Bookstaber (1981) re-evaluated the Chiras and Manaster (1978) study, which employed closing stock and stock options price data, and found that over 70 percent of the tested riskless hedging positions had observed profits due to non-contemporaneous data.

The second issue is the estimation of the volatility parameter. It is well-documented (e.g. Hauser and Neff, 1985) that BOPM values are highly sensitive to changes in volatility. Hence, a number of different volatility estimators have been tested in previous studies of futures options pricing. These can be categorized two primary groups: historical volatility estimators and implied volatility estimators.

Historical volatility estimators are based on historical prices for the underlying futures contract. The simplest historical estimator is the standard deviation of futures price changes for the previous X days. Typically, X is between 20 and 40 days and closing prices are used to calculate price changes. More complex estimators are based on high, low, and closing prices (Beckers, 1983).

Implied volatility estimators are based on the assumption that options markets efficiently incorporate all available information and that the given options pricing model is an unbiased predictor of equilibrium premiums. Based on these assumptions, a market consensus estimate of volatility can be derived from realized market premiums. Specifically, numerical procedures are used to iteratively search for the volatility estimate that equates the option pricing model's value to the realized market premium. The resultant "implied" volatility estimate can be used as an input to value options traded in a subsequent period.

Empirical Studies of Futures Option Pricing

A number of empirical studies have examined the performance of futures options pricing models. However, only Shastri and Tandon (1986a,1986b), Whaley (1986), Jordan, Seale, McCabe, and Kenyon (1987) and Followill (1987) have used contemporaneous futures and options data.[3]

Shastri and Tandon (1986a) compared the performance of the BOPM with the American model proposed by Geske and Johnson (1984). The data consisted of all contemporaneous futures and options prices for the S&P 500 from January 1983 through September 1984 and the German Mark from January through December 1984. Both a 40-day historical volatility estimator and an implied volatility estimator based on at-the-money options were employed. Only accuracy test results were reported in the study.

Pricing deviations of model and market premia ranged between -2.0 and +11.9 percent of market option premia. With the exception of puts on the S&P 500, the implied volatility estimator provided the most accurate estimates. No significant differences were reported in the pricing accuracy of the BOPM and the Geske and Johnson American pricing model. Both models and both volatility estimators over-priced S&P 500 calls, while S&P 500 puts were under-priced using implied volatility and over-priced using historical volatility. German Mark options were under-valued in all cases. Based on a categorical analysis, the difference between market and model prices did not appear to be related to moneyness or time-to-maturity.

Shastri and Tandon (1986b) extended their earlier analysis of Geske and Johnson's (1984) American model by conducting accuracy, bias, and efficiency tests. The data were basically the same as for their previous study. Again, both a 40-day historical volatility estimator and an implied volatility estimator based on at-the-money options were employed.

Average pricing deviations were similar to those reported in the earlier study, with the exception that the pattern of mis-pricing was reversed for S&P 500 puts. Since these findings were stable when sample periods were split in half, Shastri and Tandon argued that mis-pricing could not be attributed to pricing inefficiencies that may exist in new markets.

To test for systematic biases, the pricing deviations were regressed on time-to-maturity and the moneyness of the option. Significant time-to-maturity and moneyness biases were found for both estimators of variance, both puts and calls, and both futures contracts, but the direction of bias was not consistent. In addition, the constant terms were significant, indicating that other systematic biases may exist.

Shastri and Tandon conducted efficiency tests to determine if abnormal hedging profits were possible using the Geske and Johnson pricing model. The performance of the hedging strategy was examined for two possible liquidation points: 1) one trade after execution, and 2) two trades after execution. Excess gross profits relative to the risk-free rate of return were reported from hedge portfolios of both S&P 500 and German Mark futures and options contracts. Significant excess returns were still evident after considering

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[3]Studies using closing futures and options price data include Figlewski and Fitzgerald (1982), Hauser and Neff (1985), Wolf and Pohlman (1988), and Wilson, Fung, and Ricks (1988).

the transactions costs of a floor trader. However, these results were dependent upon the ability to execute the strategy at the pre-specified prices. If the strategies were executed one trade after the pricing deviation was observed, all excess returns were eliminated.

Whaley (1986) examined the pricing performance of the BAWOPM using all contemporaneous prices for S&P 500 futures and options for the period January 2, 1983 through December 30, 1983. The implied volatility estimator was based on a non-linear regression procedure that used all option observations for a given day (Whaley, 1982). Maturity and moneyness biases were evident for both calls and puts. For calls, out-of-the-money options were over-priced and in-the-money options were under-priced. For puts, just the opposite was true. The maturity bias was the same for both puts and calls: short time-to-expiration options were over-priced and long time-to-expiration options were under-priced. Whaley noted that the maturity bias appeared to be more serious for put options.

Two riskless hedging strategies were used to test the efficiency of the S&P 500 futures options market over the sample period. The first, a buy-and-hold portfolio, was held until the expiration of the option. The second, a re-balanced portfolio, was also held until expiration of the option, but hedge positions were re-balanced daily. Both strategies generated abnormal risk-adjusted rates of return after transactions costs assumed to be incurred by floor traders and institutional investors. However, Whaley argued that higher transaction costs likely would eliminate abnormal profits for retail investors.

Jordan, Seale, McCabe, and Kenyon (1987) investigated the pricing performance of the BOPM for soybean futures options. The data set consisted of all contemporaneous transactions for soybean options and futures contracts over the period of October 31, 1984 through May 31, 1985. Three estimates of volatility were used. The first was a twenty-day historical volatility estimator. The second was a regression estimator based on time-to-maturity, seasonality, the futures price level. The third was the implied volatility for the put or call option nearest to at-the-money.

Jordan et al. found the BOPM was a highly accurate model for pricing options on soybean futures when the volatility input was the implied volatility estimator. For calls, the BOPM underpriced soybean options by an average of only four-hundredths of a cent per bushel. For puts, options were underpriced on average by one-tenth of a cent per bushel. In contrast, when the historical volatility estimator was used, the BOPM underpriced soybean call and put options by over one cent per bushel.

A systematic moneyness bias of the pricing deviations was found. At-the-money call and put option were slightly over-priced by the BOPM, but the model progressively under-priced as options became further in- and out-of-the-money. Tests for maturity effects, trends in volatility, and price support bias produced mixed results.

Followill (1987) conducted an efficiency test of the BOPM by identifying instances of possible relative mis-pricing of gold call futures options.

Specifically, vertical options positions were examined that consisted of the simultaneous purchase and sale of call options differing only by strike prices. The data sample included contemporaneous gold futures and options prices for the periods May 14, 1984 through July 9, 1984 and September 17, 1984 through November 9, 1984. The BOPM was used to detect instances of relative call futures options mis-pricing. Whaley's (1982) iterative technique for calculating implied volatility was used as the volatility estimator. Positions were exited after the mis-pricing was no longer evident or options expired, whichever occurred first.

Significant risk-adjusted profits were observed before transactions costs. However, these profits were reduced by 93 percent after accounting for clearing costs and liquidity costs. Large losses were generated after adjusting for costs likely to be incurred by retail traders. Followill did find significant trading profits if a filter rule based on substantial deviations between market and model prices was used to enter or exit trades.

III. DATA AND VARIABLE ESTIMATION

Futures and Options Data

The future and options data used in this study were obtained from the Chicago Mercantile Exchange (CME). The original data set consisted of all transactions reported on the CME's "Quote Capture Request" log of transaction data for live cattle and feeder cattle futures and options contracts. The live cattle sample period began on the first day of live cattle options trading, October 31, 1984, and continued through September 30, 1988. The sample for feeder cattle was intended to begin on the first day of trading in feeder cattle options, January 9, 1987, and continue through September 30, 1988. Unfortunately, a technical error at the CME permanently deleted the feeder cattle options price data for all of 1987. Thus, the feeder cattle sample period was January 4, 1988 through September 30, 1988.

The original data set contained over two million observations. In order to reduce the original data set to a manageable size, one observation per day for all put and call contracts and all strike prices was collected. Contemporaneous futures prices were collected to match the put and call observations. To avoid induced volatility resulting from prices collected at different times of the day and price distortions around the open and close of the market, the period from 10:00 a.m. and 12:00 a.m. was chosen to collect the options and futures prices.[4]

The matching of futures and options data proceeded as follows. First, for each strike price and contract, the option trading nearest to 11:00 a.m.

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[4]Jordan, Seale, Dinehart, and Kenyon (1988) found that the intraday variance of soybean futures prices is 30 percent higher during the first and last forty-five minutes of trading.

was obtained. The option was selected based on the minimum absolute difference between the time of the option transaction and 11:00 a.m. This criterion was used as their is no a priori reason to expect futures to lead options or vice versa. To obtain the contemporaneous futures price, a criterion of a maximum of 60 seconds between futures and options transactions was used. The criterion was arrived at after testing various windows between 300 and 20 seconds. It was found that the mean and standard deviation of the absolute time difference between the futures and options transactions declined without a large loss of observations until the window approached 60 seconds. Further reductions produced a substantial decrease in observations with no reduction in mean or standard deviation of absolute time differences.

The next step was to eliminate options with extremely low premiums. Shastri and Tandon (1986b) note that deep out-of-the-money options should be deleted since the hedging strategies that underly the pricing models require an unrealistic investment in such options. Hence, options with a premium of less than or equal to $.05 per hundredweight were deleted. This filter deleted a total of 125 observations for live cattle calls, 201 live cattle puts, 11 feeder cattle calls, and 25 feeder cattle puts.

A summary description of the futures and options data is presented in Table 1. The final data base included 10,400 observations for live cattle calls, 9,710 observations for live cattle puts, 880 observations for feeder cattle calls, and 1,197 observations for feeder cattle puts. The mean absolute times between futures and options observations range from 16.17 seconds for live cattle calls to 25.63 seconds for feeder cattle puts.

Variable Estimation

The values for the futures price, observed option premium, expiration date, and strike price needed to calculate BOPM and BAWOPM model prices for each daily observation were taken directly from the "Quote Capture Request" tapes provided by the CME. Time-to-expiration was calculated as a proportion of a year (365 days) remaining to expiration. The riskless interest rate was estimated as the 90-day Treasury bill rate and was provided by the Federal Reserve Bank of Cleveland.

Consistent with previous studies, both historical and implied volatility estimators were employed. Historical volatility (annualized) for day t was calculated as the standard deviation of the twenty futures price changes previous to day t. The futures price nearest 11:00 a.m. was used in calculating historical volatilities. The twenty-day sample period was selected due to its popularity among options traders (Jarrow and Rudd, 1983).

Generally, implied volatility estimates obtained from options on the same futures contract, but with different strike prices, will not be equal. Day and Lewis (1988) suggest this is do to the fact that implied volatility estimates contain two significant sources of noise. The first is the inability to determine whether option and underlying securities prices reflect bid or ask levels. The second is the failure to exactly match the observed option price with the contemporaneous price of the underlying security.

A number of implied volatility estimators have been proposed in light of the observed deviations in estimates for different options on the same security. Methods of combining estimates include an arithmetic average of implied volatilities for all options on a security, an average weighted by the partial derivative of the option with respect to volatility, and an average weighted by the elasticity of the option to volatility.

Previous studies of futures options pricing did not compare alternative implied volatility estimators. Hence, three implied volatility estimators were used in this study. The first estimate was an arithmetic average of the previous trade day's implied volatilities for all options sampled for a given maturity. The average estimate incorporates information from all options for a given maturity. The second estimate was the implied volatility for the sampled option nearest to at-the-money. This estimate reflects the implied volatility for the option most sensitive to changes in volatility. The third estimate was the implied volatility of the previous day's option with a strike price most closely matched to the option being priced. The matched estimate is based on the finding from previous studies that pricing errors are related to the moneyness of the option (e.g. Jordan, Seale, McCabe, and Kenyon, 1987). In all cases separate estimates were made for calls and puts. Finally, all implied volatilities were estimated using a Newton-Raphson iterative search algorithm.

The volatility estimates for live cattle and feeder cattle for the entire sample period are summarized in Table 2. The mean and standard deviation of historical volatility were consistently smaller than the implied volatility estimates. This was evident not only for the entire data set, but also broken out by contract.[5] Differences among the mean and standard deviation of the three implied volatility estimates for live cattle were minimal across puts and calls and the European and American option model estimates. However, mean implied volatilities for feeder cattle call options averaged approximately two percentage points less than implied volatilities for feeder cattle put options. Also, the standard deviations of the implied volatilities for feeder cattle put options were higher than for feeder cattle calls. Differences between American and European model estimates for feeder cattle calls and puts were minimal.

IV. RESULTS OF PERFORMANCE TESTING

Eight theoretical model values were calculated for both puts and calls (four volatility estimates in both the European and American option pricing models). Accuracy and bias tests were applied to each set of model values. Efficiency tests were not conducted because of the previously discussed problems in measuring transaction costs, in adjusting positions such that hedges are riskless, and in specification of a theoretically valid equilibrium model to adjust hedging returns for risk.

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[5]Individual contract results are presented in Pelly (1989).

<u>Accuracy tests</u>

The results of the accuracy tests are presented in Tables 3 and 4. Four general conclusions may be drawn from these tables:

1) With the exception of average implied volatility for feeder cattle, model put and call values were underpriced relative to the market premiums.

2) There were minute differences between the European and American models across volatility estimators and option types.

3) Historical volatility generated a larger difference between model and market prices than the implied volatilities. The average deviation of the European model using historical volatility for live cattle calls was $0.3599/cwt. and for puts $0.3724/cwt.; the corresponding deviations for feeder cattle were $0.3165/cwt. for calls and $0.4497/cwt. for puts. In contrast, the largest average deviation of the three implied volatility forecast estimates was only $0.044/cwt.

4) Average implied volatility was generally the most accurate volatility estimator. However, the differences across the three implied volatility estimators were small with the exception of the at-the-money implied volatility estimator for live cattle and feeder cattle puts, which was substantially less accurate.

The percent of option premiums over-priced and under-priced was consistent with the evidence on average accuracy. Historical volatility grossly under-priced when compared to the implied volatility estimates. There was little difference in the degree of under-pricing among average, at-the-money, and strike price matched implied volatility estimates for live cattle and feeder cattle calls. For live cattle and feeder cattle puts, at-the-money implied volatility under-priced to a greater degree than either average or strike priced implied volatility.

<u>Bias tests</u>

Previous researchers have conducted bias tests by regressing the difference between actual and model prices on time-to-maturity, moneyness, and volatility. The bias tests utilized in this study included a larger set of variables in order to examine additional sources of systematic pricing error. The additional variables include: 1) the riskless interest rate, 2) option market liquidity, 3) seasonal dummy variables, and 4) contract dummy variables.

The riskless interest rate was included on the basis being an exogenous variable to the pricing models, as are time-to-maturity, moneyness, and volatility. Option market liquidity was included based on an entry and exit cost argument. Specifically, observed market premia may reflect differences in entry and exit costs between liquid and illiquid markets, in addition to more fundamental factors. Since the BOPM and BAWOPM were derived based on an assumption of frictionless markets, pricing errors may be related to differences in market liquidity. The time difference between the traded option and 11:00 a.m. (in seconds) was used as a measure of market liquidity.

Seasonal and contract dummy variables were included in the bias regressions to examine specific time effects on pricing errors. The dummy variables were defined to equal one for a specific month or contract and zero otherwise. Finally, note that the length of the feeder cattle sample period precluded the use of contract and seasonality dummy variables in feeder cattle bias regressions.

All bias equations were estimated via Ordinary Least Squares. Because, all else constant, standard errors for the parameters will decline as number of observations increases, t-values and F-values may become inflated with a large number of observations (Leamer, 1978). Since sample sizes for this study are large, ranging from 880 to 10,400, critical t- and F-values were calculated according to Leamer's (1978) formulas,

$$F^* = [(T - k)/p][T^{p/T} - 1] \tag{13}$$

$$t^* = [(T - k)(T^{1/T} - 1)]^{0.5} \tag{14}$$

where

T = total number of observations,

k = total number of parameters,

p = total number of restrictions.

Using the above formulas, the critical t-values for the coefficients of the live cattle call (put) bias equations are 3.07 (2.95). The critical regression F-values for the live cattle call and (put) equations are 9.41 (9.26). The critical F-values for live cattle calls (puts) for joint tests of contract maturity effects and seasonal effects are 9.19 (9.12) and 9.50 (9.51), respectively. For feeder cattle calls (puts) the critical t-values for the coefficient estimates are 2.65 (2.73) and the critical F-value for the regression equations are 6.87 (7.12).

Live Cattle Calls

Bias test results for live cattle calls are presented in Tables 5 through 8. The results varied only slightly across the European and American option pricing models. Coefficients for all variables, except one contract dummy and three seasonal dummies, were significant for the historical volatility equations. When an implied volatility estimator was used, a significant reduction occurred in both the magnitude and number of significant coefficients. Among the variables, only volatility and the August contract dummy variable coefficients were significant in all six implied volatility bias equations. The time-to-maturity coefficient was significant in the average and at-the-money implied volatility equations. The moneyness coefficient was significant only in the equation for the American model using the strike price matched implied volatility estimator. The intercept and coefficients for the riskless interest rate and liquidity were insignificant in all six implied volatility equations.

The six implied volatility equations varied in the number of significant coefficients for contract dummy variables from a high of two for the strike price matched volatility equations to zero for average and at-the-money implied volatility equations. The dummy variable coefficients were not jointly significant in any implied volatility equation. These results suggest that pricing deviations for live cattle call options were not strongly affected by contract effects when implied volatility was used. Furthermore, size of the coefficients varied little by contract. Thus, no systematic pricing bias was found in the initial period of trading in live cattle call contracts.

For the seasonal dummy variables, the number of significant coefficients ranged from three for the average and strike price matched equations to one for the at-the-money equation, and the month of August exhibited the only common significant coefficient. However, the seasonal coefficients were jointly significant in the average and strike price matched equations. These results indicate that exogenous factors specific to any particular month may have influenced the systematic pricing biases for live cattle call options.

The summary statistics for live cattle calls indicate the regression specifications of both American and European option pricing models using historical volatility provided a reasonably good explanation for the pricing deviations. These models had an R^2 of .7679 and .7703, respectively. However, the R^2 values for the models using the three implied volatility estimates ranged from a high of .0573 to a low of .0393, indicating the pricing deviations were not well explained by the selected independent variables. The low R^2 values suggest that when an implied volatility estimator was used, the pricing deviations between market and model premia were not due to variables used in computing the model premia, and largely consisted of random noise.

Live Cattle Puts

The bias test results for live cattle puts are presented in Tables 9 through 12. Similar to live cattle calls, the results varied only slightly across the European and American option pricing models. Likewise, almost all coefficients were significant in the historical volatility equations, and the magnitude and number of significant coefficients declined when historical volatility was replaced by the three implied volatility estimates. However, when compared to the results for live cattle calls, the decline in the number of significant variables was smaller and different variables tended to be significant in the implied volatility equations. Moneyness and riskless interest rate coefficients were significant in five of the six implied volatility equations. The intercept and time-to-maturity coefficients were significant in the average and at-the-money equations, but not the strike price matched equations. The volatility coefficient was significant only in the average implied volatility equations and the liquidity coefficient was insignificant in all implied volatility equations.

While the coefficients for most contract dummies were individually significant in all six implied volatility equations, they were jointly significant only in the at-the-money equations. Similar to live cattle calls, this was not strong evidence that pricing deviations were affected by contract effects when implied volatility was used. Also, since the size of the coefficients varied little by contract, a systematic pricing bias that could be attributed to the initial period of trading on live cattle put contracts was not found.

Only a few of the estimated coefficients for the seasonal dummy variables were individually significant, and only for the average implied volatility equations were the seasonal coefficients jointly significant. In general, these results suggest that exogenous factors specific to any particular month did not strongly influence the systematic pricing biases for live cattle puts.

As with live cattle calls, the pricing bias equation for historical volatility had a relatively high R^2, approximately 0.73. This value suggested that the independent variables were explaining a majority of the bias. The R^2 values for the models using the three implied volatility estimates showed more variation than those for live cattle calls, ranging from a high of .1006 to a low of .0271, but still indicated that the pricing deviations were not well explained by the selected independent variables.

Feeder Cattle Calls and Puts

The pricing bias regression results for the feeder cattle futures options are presented in Tables 13 through 16. Again, the results varied only slightly across the European and American option pricing models. For feeder cattle calls, historical volatility generated significant coefficients for time-to-maturity, volatility, and the riskless interest rate. Both the number of significant coefficients (for comparable groups of variables) and the R^2 values for historical volatility were substantially less than for live cattle calls. Only three coefficients were significant in the six implied volatility equations: time-to-maturity for the American and European average implied volatility equations and the intercept for the European average implied volatility equation. Not surprisingly, the R^2 for the implied volatility equations were near zero and the regression F-statistics were not significantly different from zero.

Coefficients for three variables were significant for the historical volatility equation for feeder cattle puts: time-to-maturity, volatility, and the riskless interest rate. Note that the same coefficients were significant for the historical volatility equation for feeder cattle calls. The R^2 values for the historical volatility equations for feeder cattle puts were substantially less than for live cattle puts. For all six implied volatility equations, the intercept and moneyness and volatility coefficients were significant. The significance of the intercepts and volatility coefficients was the only case where coefficients were significant in implied volatility equations but not the historical volatility equations. Coefficients for time-to-maturity, the riskless interest rate, and liquidity were not significant in any of the implied volatility equations.

The explanatory power of the implied volatility equations for feeder cattle puts, with R^2s ranging from .0428 to .1297, was substantially higher than for feeder cattle calls. Corresponding regression F-statistics for the feeder cattle puts were significantly different from zero. It is interesting to note that, compared to calls, both the number of significant variables and R^2s were larger for the implied volatility equations for puts on live cattle and feeder cattle.

Interpretation of Bias Parameters

Previous empirical studies have presented bias results in terms of over-pricing or under-pricing options relative to the actual market price. Such statements are dependent on the range of data used to estimate the equations and the location of the regression line with respect to the y-intercept, which in turn depends on the values of the independent variables. For example, a positive and significant coefficient for time-to-maturity may imply that (1) over-pricing diminishes as time-to-maturity increases, (2) under-pricing increases as time-to-maturity increases, or (3) a combination of the two effects occurs.

Figures 1 through 8 were produced to facilitate the discussion of over-pricing and under-pricing bias due to a specific variable. Since the difference in bias test results for the European and American models was negligible, bias relationships are presented only for the European model. Further, to emphasize the difference in results across volatility estimators, bias relationships are presented for variables with significant coefficients in both historical volatility and average implied volatility equations. The relationships were generated for a given estimated equation by varying one independent variable and setting all others equal to their mean values, and in the case of live cattle, setting dummy variables equal to zero.[6] With the exception of implied volatility, independent variables were varied over the range of data used to estimate the equation. Implied volatility was varied over the same range as historical volatility for comparison purposes. Only a small proportion of implied volatilities fell outside the range of historical volatilities.

Figures 1,2, and 3 indicate that shorter time-to-maturity options were

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[6]Setting the indicated dummy variables to zero implies that the equations are based on the June 1989 contracts and the month of December.

under-priced less than longer time-to-maturity options for live cattle calls, live cattle puts, and feeder cattle puts, respectively. Note also that the magnitude of the time-to-maturity bias was substantially less for the average implied volatility estimator than for the historical volatility estimator.

Figures 4, 5, and 6 show the volatility bias for live cattle calls and puts and feeder cattle puts. In all three cases, low volatility options were under-priced using historical and average implied volatility, with the magnitude of the under-pricing substantially larger for historical volatility. However, as volatility increases the under-pricing decreased for historical volatility but increased slightly for implied volatility. High volatility options for live cattle calls and feeder cattle puts were over-priced using historical volatility.

Figures 7 and 8 indicate similar moneyness and riskless interest rate biases for live cattle puts. While under-pricing increased for the implied volatility estimator as the moneyness ratio and riskless interest rate increased, for all values the bias was substantially less for the average implied than historical volatility.

V. SUMMARY AND IMPLICATIONS

A limited number of studies have investigated the performance of options pricing models for commodity futures options using contemporaneous futures and options data, and none have examined the performance of option pricing models in the live cattle and feeder cattle markets. This study investigated the performance of Black's European model and Barone-Adesi and Whaley's American model in pricing live cattle and feeder cattle futures options.

One historical and three implied volatility estimators were employed. The historical volatility estimator was the twenty-day standard deviation of actual price changes. The implied volatility estimators were: (1) an equally-weighted average of the previous trade day's implied volatility for all strike prices sampled for a given option maturity, (2) the implied volatility for the previous trade day's option closest to at-the-money, and (3) the implied volatility of the previous day's option with a strike price most closely matched to the option being priced.

The live cattle sample period was October 31, 1984 through September 30, 1988. The feeder cattle sample period was January 4, 1988 through September 30, 1988. One observation per day for all put and call contracts and all strike prices was collected. Contemporaneous futures prices were collected to match the put and call observations. Mean absolute times between futures and options observations ranged from 16.17 seconds for live cattle calls to 25.63 seconds for feeder cattle puts. The final data base included 10,400 observations for live cattle calls, 9,710 observations for live cattle puts, 880 observations for feeder cattle calls, and 1,197 observations for feeder cattle puts.

Black's European model was as accurate in predicting premiums as Barone-Adesi and Whaley's American model across all volatility estimates and option contracts. This result mirrors the findings of previous empirical research for financial futures options contracts (Shastri and Tandon, 1986a) and is consistent with the generally observed low use of early exercise on U.S. futures options markets. Similar to results of both equity options and financial futures options pricing studies, implied volatility estimates generated substantially more accurate forecasts of actual option premia than historical volatility. Small differences were found in the predictive ability among the three implied volatility estimates.

The significance and signs of the coefficients and explanatory power of the bias regressions were generally consistent across both option pricing models, suggesting that little difference in biases existed between the American and European model. With the exception of the intercept and moneyness coefficients for feeder cattle puts, no variable coefficients were significant in an implied volatility bias regression that were not also significant in the historical volatility equation. Furthermore, for both live cattle and feeder cattle calls, substantially fewer variables were significant in the implied volatility equations. In addition, the magnitude of bias associated with variables in the implied volatility equations was substantially less than that of variables in historical volatility equations. Finally, it was found that none of the variables input into the option pricing models (time-to-maturity, moneyness, volatility, and the riskless interest rate) displayed consistently significant coefficients across markets and option type.

These observations suggest that implied volatility captured most, but not all, of the bias that resulted from using historical volatility. While biases continued to exist for implied volatilities, the low R^2s for the bias equations suggest that the mis-pricing of options was due to factors exogenous to the option pricing models.

The results of this study suggest three areas for further research. The first is whether these results can be duplicated in other agricultural options markets. The second is whether implied volatility-based models are able to generate significant speculative trading profits. The third is identification of the reasons that implied volatility reduces mis-pricing. It is suggested that implied volatilities capture the effects of other variables, such as moneyness and interest, but research is needed to confirm or reject this observation.

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TABLE 1. LIVE CATTLE AND FEEDER CATTLE OPTIONS AND FUTURES DATA BASE DESCRIPTIONS

		TIME BETWEEN OPTION AND TRADED FUTURES CONTRACT		TIME BETWEEN TRADED OPTION AND 11:00 a.m.	
	OBSERVATIONS	μ	σ	μ	σ
		-----SECONDS------		---MINUTES.SECONDS---	
Live Cattle:[a]					
Calls	10,400	16.17	14.35	18.22	16.20
Puts	9,710	16.21	14.44	19.44	16.37
Feeder Cattle:[b]					
Calls	880	23.91	16.59	25.65	17.71
Puts	1,197	25.63	16.74	25.32	17.69

[a]The live cattle sample includes all options contracts over the period October 31, 1984 through September 30, 1988.
[b]The feeder cattle sample includes all options contracts over the period January 9, 1988 through September 30, 1988.

TABLE 2. SUMMARY OF VOLATILITY ESTIMATES FOR LIVE CATTLE AND FEEDER CATTLE PRICES

	VOLATILITY ESTIMATE[a]						
	HV	AIV1	EIV1	AIV2	EIV2	AIV3	EIV3
	ANNUALIZED PERCENT						
LIVE CATTLE:							
μ							
CALLS	16.00	20.74	20.83	20.47	20.52	20.70	20.77
PUTS	15.89	20.88	20.95	20.34	20.40	20.77	20.83
σ							
CALLS	5.79	7.46	7.45	7.47	7.47	7.66	7.65
PUTS	5.88	7.44	7.44	7.09	7.08	7.51	7.50
FEEDER CATTLE:							
μ							
CALLS	14.67	18.37	18.44	18.23	18.27	18.30	18.36
PUTS	14.39	20.22	20.26	19.54	19.58	20.06	20.09
σ							
CALLS	4.43	7.76	7.75	7.94	7.94	7.96	7.96
PUTS	4.26	9.22	9.22	9.21	9.20	9.26	9.25

[a]HV = 20 day historical volatility estimate.
AIV1 = Averaged put or call American implied volatility estimate.
EIV1 = Averaged put or call European implied volatility estimate.
AIV2 = At-the-money put or call American implied volatility estimate.
EIV2 = At-the-money put or call European implied volatility estimate.
AIV3 = Strike price matched put or call American implied volatility estimate.
EIV3 = Strike price matched put or call European implied volatility estimate.

TABLE 3. ACCURACY RESULTS COMPARING MARKET AND MODEL PRICES FOR LIVE CATTLE OPTIONS.

MODEL	VARIANCE ESTIMATE[c]	PRICING DEVIATIONS[a] μ	PRICING DEVIATIONS[a] σ	FREQUENCY OF MODEL MIS-PRICING[b] % < 0	FREQUENCY OF MODEL MIS-PRICING[b] % = 0	FREQUENCY OF MODEL MIS-PRICING[b] % > 0
		-----$/cwt.------		--------PERCENT--------		
CALLS (OBS = 10,275):						
EUROPEAN	HV	0.3599	0.4801	15.9	0.9	83.2
	IV1	0.0081	0.1127	43.7	5.4	50.9
	IV2	0.0174	0.1162	39.3	4.7	56.0
	IV3	0.0147	0.1155	40.7	5.6	53.7
AMERICAN	HV	0.3548	0.4806	16.2	1.0	82.8
	IV1	0.0091	0.1120	42.9	5.5	51.6
	IV2	0.0172	0.1159	39.4	.8	55.8
	IV3	0.0143	0.1153	40.9	5.6	53.6
PUTS (OBS = 9,509):						
EUROPEAN	HV	0.3724	0.4626	14.0	0.9	85.1
	IV1	0.0008	0.1197	44.2	4.5	51.3
	IV2	0.0301	0.1232	33.3	4.4	62.2
	IV3	0.0129	0.1417	40.0	5.7	54.3
AMERICAN	HV	0.3776	0.4641	14.3	0.8	84.9
	IV1	0.0008	0.1236	44.1	4.5	51.4
	IV2	0.0302	0.1238	33.2	4.4	62.4
	IV3	0.0124	0.1418	40.2	5.7	54.1

[a]The pricing deviations were calculated as market price - model price.
[b]If the model under (over) prices the actual premium, the deviation will be > 0 (< 0).
[c]HV = 20-day historical volatility estimate.
IV1 = Averaged put or call implied volatility estimate.
IV2 = At-the-money put or call implied volatility estimate.
IV3 = Strike price matched put or call implied volatility estimate.

TABLE 4. ACCURACY RESULTS COMPARING MARKET AND MODEL PRICES FOR FEEDER CATTLE OPTIONS.

MODEL	VARIANCE ESTIMATE[c]	PRICING DEVIATIONS[a] μ	σ	FREQUENCY OF MODEL MIS-PRICING[b] % < 0	% = 0	% > 0
		-----$/cwt.------		--------PERCENT--------		
CALLS (OBS = 869):						
EUROPEAN	HV	0.3165	0.5987	26.9	0.7	72.7
	IV1	0.0006	0.2945	49.5	3.0	47.5
	IV2	0.0019	0.2110	51.3	1.7	47.0
	IV3	0.0071	0.2103	48.0	1.2	50.9
AMERICAN	HV	0.3119	0.5989	26.9	1.5	71.6
	IV1	0.0010	0.2030	48.9	3.2	47.9
	IV2	0.0009	0.2102	50.7	2.9	46.4
	IV3	0.0065	0.2096	47.8	1.5	50.7
PUTS (OBS = 1,172):						
EUROPEAN	HV	0.4497	0.5880	17.5	1.0	81.5
	IV1	-0.0123	0.1974	48.9	2.6	48.5
	IV2	0.0437	0.1915	35.4	2.0	62.6
	IV3	0.0121	0.1899	44.0	3.7	52.3
AMERICAN	HV	0.4464	0.5880	17.9	0.7	81.4
	IV1	-0.0122	0.1994	48.5	2.6	48.9
	IV2	0.0441	0.1929	34.9	2.4	62.7
	IV3	0.0117	0.1910	43.9	3.9	52.1

[a]The pricing deviations were calculated as market price - model price.
[b]If the model under (over) prices the actual premium, the deviation will be > 0 (< 0).
[c]HV = 20-day historical volatility estimate.
IV1 = Averaged put or call implied volatility estimate.
IV2 = At-the-money put or call implied volatility estimate.
IV3 = Strike price matched put or call implied volatility estimate.

TABLE 5. PRICING BIAS REGRESSIONS FOR LIVE CATTLE CALL OPTION PRICING MODELS: HISTORICAL VOLATILITY ESTIMATE.[a]

	AMERICAN MODEL			EUROPEAN MODEL		
INDEPENDENT VARIABLE[b]	COEF-FICIENT[c]	T VALUE	P VALUE	COEF-FICIENT	T VALUE	P VALUE
INTERCEPT	2.0764*	20.17	.0001	1.9721*	19.27	.0001
TTM	0.4716*	24.15	.0001	0.5042*	25.97	.0001
MONEYNESS	0.6594*	14.32	.0001	0.7539*	16.47	.0001
VOLATILITY	-5.1385*	-86.15	.0001	-5.1096*	-86.19	.0001
INTEREST	-9.7640*	-13.38	.0001	-9.6197*	-13.27	.0001
LIQUIDITY	-0.0001*	-10.61	.0001	-0.0001*	-10.42	.0001
CONTRACT DUMMIES						
02/85	-1.2783*	-14.28	.0001	-1.2823*	-14.41	.0001
04/85	-1.1343*	-13.98	.0001	-1.1397*	-14.13	.0001
06/85	-0.9746*	-12.23	.0001	-0.9782*	-12.35	.0001
08/85	-0.9713*	-12.31	.0001	-0.9764*	-12.45	.0001
10/85	-0.8175*	-10.36	.0001	-0.8238*	-10.51	.0001
12/85	-1.0941*	-13.89	.0001	-1.0985*	-14.03	.0001
02/86	-0.9533*	-12.10	.0001	-0.9573*	-12.22	.0001
04/86	-0.7404*	-9.37	.0001	-0.7447*	-9.48	.0001
06/86	-0.6389*	-8.09	.0001	-0.6426*	-8.19	.0001
08/86	-0.7053*	-8.93	.0001	-0.7097*	-9.04	.0001
10/86	-0.9218*	-11.67	.0001	-0.9258*	-11.80	.0001
12/86	-0.9882*	-12.50	.0001	-0.9910*	-12.61	.0001
02/87	-1.0662*	-13.43	.0001	-1.0695*	-13.55	.0001
04/87	-1.0632*	-13.40	.0001	-1.0668*	-13.53	.0001
06/87	-1.1973*	-15.15	.0001	-1.1998*	-15.27	.0001
08/87	-1.2117*	-15.35	.0001	-1.2149*	-15.49	.0001
10/87	-1.1565*	-14.72	.0001	-1.1607*	-14.86	.0001
12/87	-1.0392*	-13.24	.0001	-1.0424*	-13.36	.0001
02/88	-1.0089*	-12.82	.0001	-1.0125*	-12.95	.0001
04/88	-1.0138*	-12.87	.0001	-1.0162*	-12.98	.0001
06/88	-0.9316*	-11.82	.0001	-0.9342*	-11.93	.0001
08/88	-1.0310*	-13.12	.0001	-1.0343*	-13.24	.0001
10/88	-0.9613*	-12.28	.0001	-0.9654*	-12.41	.0001
12/88	-0.4188*	-5.36	.0001	-0.4218*	-5.43	.0001
02/89	0.0844	1.08	.2826	0.0813	1.04	.2976
04/89	0.5146*	6.46	.0001	0.5114*	6.46	.0001

TABLE 5. (CONT'D.)

INDEPENDENT VARIABLE	AMERICAN MODEL COEF-FICIENT	T VALUE	P VALUE	EUROPEAN MODEL COEF-FICIENT	T VALUE	P VALUE
SEASONAL DUMMIES						
JAN	-0.0338	-2.57	.0101	-0.0342	-2.62	.0088
FEB	-0.1462*	-10.77	.0001	-0.1468*	-10.89	.0001
MAR	-0.1646*	-12.02	.0001	-0.1161*	-12.21	.0001
APR	-0.1602*	-11.29	.0001	-0.1606*	-11.39	.0001
MAY	-0.1520*	-10.88	.0001	-0.1542*	-10.97	.0001
JUNE	0.0162	1.15	.2429	0.0160	1.14	.2527
JULY	-0.0381	-2.72	.0065	-0.0389	-2.80	.0052
AUG	-0.2173*	-15.72	.0001	-0.2175*	-15.84	.0001
SEPT	-0.1194*	-8.91	.0001	-0.1196*	-8.98	.0001
OCT	-0.0512*	-3.79	.0002	-0.0516*	-3.84	.0001
NOV	-0.1154*	-8.33	.0001	-0.1162*	-8.45	.0001

SUMMARY STATISTICS

	AMERICAN MODEL	EUROPEAN MODEL
R^2	0.7679	0.7703
ADJUSTED R^2	0.7670	0.7694
F(REGRESSION)[d]	806.1950*	817.1790*
p-value	(.0001)	(.0001)
F(SEASONALITY)[e]	84.9896*	86.2185*
p-value	(.0001)	(.0001)
F(CONTRACT)[f]	576.5627*	584.5562*
p-value	(.0001)	(.0001)
OBSERVATIONS	10,274	

[a]The dependent variable is actual price - model price.
[b]TTM = time-to-maturity.
MONEYNESS = futures price/exercise price.
VOLATILITY = the historical volatility estimate.
INTEREST = riskless interest rate.
LIQUIDITY = difference in seconds between traded option and 11:00 a.m.
[c]* = Critical F- and t-values calculated according to Leamer (1978); t-value = 3.07 and F-value = 9.41.
[d]F(REGRESSION) = F-statistic to test hypothesis that coefficients on all variables are jointly insignificantly different from zero.
[e]F(SEASONALITY) = F-statistic to test hypothesis that coefficients on seasonal dummies are jointly insignificantly different from zero.
[f]F(CONTRACT) = F-statistic to test hypothesis that coefficients on contract dummies are jointly insignificantly different from zero.

TABLE 6. PRICING BIAS REGRESSIONS FOR LIVE CATTLE CALL OPTION PRICING MODELS: AVERAGE IMPLIED VOLATILITY ESTIMATE.[a]

	AMERICAN MODEL			EUROPEAN MODEL		
VARIABLE[b]	COEF-FICIENT[c]	T VALUE	P VALUE	COEF-FICIENT	T VALUE	P VALUE
INTERCEPT	0.0219	0.44	.6595	-0.0456	0.92	.3595
TTM	0.0723*	7.65	.0001	0.0873*	9.18	.0001
MONEYNESS	-0.0189	0.87	.3822	0.0497	2.29	.0222
VOLATILITY	0.2217*	10.24	.0001	0.2358*	10.80	.0001
INTEREST	0.3359	0.99	.3247	0.2744	0.80	.4234
LIQUIDITY	0.0001	1.94	.0520	0.0001	2.89	.0039
CONTRACT DUMMIES						
02/85	-0.0395	0.92	.3561	-0.0373	-0.87	.3860
04/85	-0.0661	-1.70	.0892	-0.0643	-1.65	.0999
06/85	-0.0605	-1.59	.1123	-0.0591	-1.54	.1228
08/85	-0.0643	-1.71	.0881	-0.0630	-1.66	.0962
10/85	-0.0720	-1.92	.0548	-0.0706	-1.87	.0610
12/85	-0.0872	-2.33	.0199	-0.0890	-2.36	.0181
02/86	-0.0769	-2.05	.0401	-0.0777	-2.07	.0388
04/86	-0.0723	-1.93	.0537	-0.0728	-1.93	.0532
06/86	-0.0776	-2.08	.0373	-0.0774	-2.07	.0389
08/86	-0.0942	-2.53	.0114	-0.0952	-2.55	.0109
10/86	-0.0888	-2.38	.0171	-0.0939	-2.51	.0121
12/86	-0.0914	-2.44	.0149	-0.0936	-2.48	.0130
02/87	-0.0726	-1.92	.0553	-0.0745	-1.96	.0503
04/87	-0.0770	-2.04	.0418	-0.0814	-2.14	.0323
06/87	-0.0746	-1.98	.0479	-0.0828	-2.19	.0287
08/87	-0.0617	-1.64	.1016	-0.0632	-1.67	.0948
10/87	-0.0640	-1.70	.0884	-0.0661	-1.75	.0796
12/87	-0.0607	-1.62	.1051	-0.0657	-1.75	.0809
02/88	-0.0686	-1.83	.0667	-0.0698	-1.86	.0632
04/88	-0.0731	-1.95	.0511	-0.0758	-2.02	.0439
06/88	-0.0649	-1.73	.0838	-0.0681	-1.81	.0707
08/88	-0.0639	-1.70	.0885	-0.0648	-1.72	.0853
10/88	-0.0670	-1.80	.0725	-0.0685	-1.83	.0673
12/88	-0.0474	-1.28	.2003	-0.0489	-1.31	.1891
02/89	-0.0421	-1.14	.2556	-0.0425	-1.14	.2531
04/89	-0.0327	-0.87	.3832	-0.0342	-0.91	.3634

TABLE 6. (CONT'D.)

VARIABLE	AMERICAN MODEL COEFFICIENT	AMERICAN MODEL T VALUE	AMERICAN MODEL P VALUE	EUROPEAN MODEL COEFFICIENT	EUROPEAN MODEL T VALUE	EUROPEAN MODEL P VALUE
SEASONAL DUMMIES						
JAN	-0.0134	-2.18	.0296	-0.0154	-2.48	.0131
FEB	-0.0110	-1.73	.0830	-0.0130	-2.05	.0407
MAR	-0.0132	-2.04	.0411	-0.0146	-2.26	.0240
APR	-0.0061	-0.91	.3614	-0.0071	-1.07	.2868
MAY	-0.0056	-0.86	.3920	-0.0088	-1.33	.1825
JUNE	-0.0076	-1.16	.2472	-0.0084	-1.27	.2041
JULY	-0.0264*	-4.08	.0001	-0.0275*	-4.24	.0001
AUG	-0.0244*	-3.77	.0002	-0.0282*	-4.33	.0001
SEPT	0.0149	2.35	.0189	0.0109	1.71	.0881
OCT	0.0094	1.48	.1377	0.0082	1.29	.1982
NOV	-0.0218*	-3.39	.0007	-0.0235*	-3.64	.0003
SUMMARY STATISTICS						
R^2		0.0543			0.0573	
ADJUSTED R^2		0.0504			0.0535	
F(REGRESSION)[d]		13.9820*			14.8200*	
p-value		(.0001)			(.0001)	
F(SEASONALITY)[e]		11.1266*			10.8518*	
p-value		(.0001)			(.0001)	
F(CONTRACT)[f]		5.1815			5.3076	
p-value		(.0001)			(.0001)	
OBSERVATIONS		10,274				

[a]The dependent variable is actual price - model price.
[b]TTM = time-to-maturity.
MONEYNESS = futures price/exercise price.
VOLATILITY = the historical volatility estimate.
INTEREST = riskless interest rate.
LIQUIDITY = difference in seconds between traded option and 11:00 a.m.
[c]* = Critical F- and t-values calculated according to Leamer (1978); t-value = 3.07 and F-value = 9.41.
[d]F(REGRESSION) = F-statistic to test hypothesis that coefficients on all variables are jointly insignificantly different from zero.
[e]F(SEASONALITY) = F-statistic to test hypothesis that coefficients on seasonal dummies are jointly insignificantly different from zero.
[f]F(CONTRACT) = F-statistic to test hypothesis that coefficients on contract dummies are jointly insignificantly different from zero.

TABLE 7. PRICING BIAS REGRESSIONS FOR LIVE CATTLE CALL OPTION PRICING MODELS: AT-THE-MONEY IMPLIED VOLATILITY ESTIMATE.[a]

	AMERICAN MODEL			EUROPEAN MODEL		
VARIABLE[b]	COEF-FICIENT[c]	T VALUE	P VALUE	COEF-FICIENT	T VALUE	P VALUE
INTERCEPT	0.0626	1.22	.2245	-0.0074	-0.14	.8864
TTM	-0.0361*	-3.76	.0002	-0.0384*	-3.99	.0001
MONEYNESS	-0.0293	-1.30	.1935	0.0451	2.00	.0458
VOLATILITY	0.1447*	-6.50	.0001	0.1446*	6.48	.0001
INTEREST	0.6295	1.78	.0759	0.6156	1.73	.0836
LIQUIDITY	0.0001	0.19	.8478	0.0001	0.81	.4187
CONTRACT DUMMIES						
02/85	-0.0619	-1.39	.1646	-0.0646	-1.45	.1482
04/85	-0.0660	-1.63	.1026	-0.0688	-1.70	.0900
06/85	-0.0744	-1.88	.0604	-0.0770	-1.94	.0527
08/85	-0.0624	-1.59	.1114	-0.0641	-1.63	.1031
10/85	-0.0588	-1.51	.1312	-0.0603	-1.54	.1231
12/85	-0.0676	-1.73	.0829	-0.0691	-1.77	.0770
02/86	-0.0873	-2.24	.0251	-0.0889	-2.28	.0229
04/86	-0.0783	-2.01	.0446	-0.0803	-2.06	.0399
06/86	-0.0878	-2.27	.0235	-0.0897	-2.31	.0210
08/86	-0.0967	-2.50	.0124	-0.0981	-2.53	.0114
10/86	-0.1002	-2.59	.0097	-0.1020	-2.63	.0087
12/86	-0.0969	-2.48	.0130	-0.0991	-2.53	.0113
02/87	-0.0786	-2.00	.0459	-0.0807	-2.04	.0410
04/87	-0.0821	-2.09	.0370	-0.0843	-2.14	.0328
06/87	-0.0779	-1.99	.0470	-0.0793	-2.02	.0436
08/87	-0.0660	-1.69	.0921	-0.0671	-1.71	.0875
10/87	-0.0594	-1.52	.1283	-0.0608	-1.55	.1204
12/87	-0.0663	-1.70	.0886	-0.0671	-1.72	.0857
02/88	-0.0611	-1.57	.1161	-0.0631	-1.62	.1060
04/88	-0.0670	-1.79	.0736	-0.0716	-1.83	.0670
06/88	-0.0898	-2.30	.0213	-0.0922	-2.36	.0185
08/88	-0.0870	-2.22	.0262	-0.0895	-2.29	.0221
10/88	-0.0564	-1.46	.1457	-0.0580	-1.49	.1361
12/88	-0.0566	-1.47	.1413	-0.0586	-1.52	.1291
02/89	-0.0509	-1.32	.1864	-0.0533	-1.38	.1678
04/89	-0.0361	-0.93	.3542	-0.0394	-1.01	.3143

TABLE 7. (CONT'D.).

VARIABLE	AMERICAN MODEL COEFFICIENT	AMERICAN MODEL T VALUE	AMERICAN MODEL P VALUE	EUROPEAN MODEL COEFFICIENT	EUROPEAN MODEL T VALUE	EUROPEAN MODEL P VALUE
SEASONAL DUMMIES						
JAN	-0.0139	-2.17	.0299	-0.0142	-2.20	.0275
FEB	-0.0066	-0.99	.3194	-0.0059	-0.90	.3700
MAR	-0.0008	-0.12	.9041	-0.0006	-0.08	.9332
APR	0.0086	1.24	.2134	0.0093	1.34	.1816
MAY	-0.0001	-0.02	.9883	-0.0004	-0.05	.9568
JUNE	-0.0006	-0.08	.9328	-0.0007	-0.10	.9228
JULY	-0.0203	-3.02	.0025	-0.0206	-3.06	.0022
AUG	-0.0216*	-3.20	.0014	-0.0214*	-3.18	.0015
SEPT	0.0129	1.96	.0496	0.0124	1.87	.0612
OCT	0.0037	0.56	.5779	0.0023	0.58	.5606
NOV	-0.0139	-2.07	.0382	-0.0144	-2.15	.0314
SUMMARY STATISTICS						
R^2	0.0450			0.0453		
ADJUSTED R^2	0.0411			0.0414		
F(REGRESSION)[d]	11.4810*			11.5560*		
p-value	(.0001)			(.0001)		
F(SEASONALITY)[e]	8.3394			8.3325		
p-value	(.0001)			(.0001)		
F(CONTRACT)[f]	5.9501			5.9444		
p-value	(.0001)			(.0001)		
OBSERVATIONS	10,274					

[a]The dependent variable is actual price - model price.
[b]TTM = time-to-maturity.
MONEYNESS = futures price/exercise price.
VOLATILITY = the historical volatility estimate.
INTEREST = riskless interest rate.
LIQUIDITY = difference in seconds between traded option and 11:00 a.m.
[c]* = Critical F- and t-values calculated according to Leamer (1978); t-value = 3.07 and F-value = 9.41.
[d]F(REGRESSION) = F-statistic to test hypothesis that coefficients on all variables are jointly insignificantly different from zero.
[e]F(SEASONALITY) = F-statistic to test hypothesis that coefficients on seasonal dummies are jointly insignificantly different from zero.
[f]F(CONTRACT) = F-statistic to test hypothesis that coefficients on contract dummies are jointly insignificantly different from zero.

TABLE 8. PRICING BIAS REGRESSIONS FOR LIVE CATTLE CALL OPTION PRICING MODELS: STRIKE PRICE MATCHED IMPLIED VOLATILITY ESTIMATE.[a]

	AMERICAN MODEL			EUROPEAN MODEL		
VARIABLE[b]	COEF-FICIENT[c]	T VALUE	P VALUE	COEF-FICIENT	T VALUE	P VALUE
INTERCEPT	0.1517	2.97	.0030	0.1267	2.48	.0133
TTM	0.0114	1.18	.2395	0.0148	1.53	.1273
MONEYNESS	-0.0877*	-3.91	.0001	-0.0625	-2.78	.0054
VOLATILITY	0.1107*	5.23	.0001	0.1138*	5.36	.0001
INTEREST	0.3917	1.11	.2686	0.3763	1.06	.2889
LIQUIDITY	-0.0001	-1.03	.3016	-0.0001	-0.81	.4199
CONTRACT DUMMIES						
02/85	-0.0806	-1.82	.0694	-0.0802	-1.80	.0712
04/85	-0.0939	-2.33	.0198	-0.0933	-2.31	.0209
06/85	-0.0952	-2.41	.0159	-0.0949	-2.40	.0165
08/85	-0.0888	-2.28	.0229	-0.0884	-2.26	.0238
10/85	-0.0972	-2.50	.0123	-0.0968	-2.49	.0129
12/85	-0.1071	-2.76	.0058	-0.1070	-2.75	.0059
02/86	-0.1034	-2.67	.0077	-0.1030	-2.65	.0081
04/86	-0.0954	-2.46	.0140	-0.0954	-2.45	.0142
06/86	-0.1034	-2.67	.0075	-0.1034	-2.67	.0076
08/86	-0.1190*	-3.08	.0020	-0.1192*	-3.09	.0020
10/86	-0.1113	-2.88	.0040	-0.1115	-2.88	.0040
12/86	-0.1201*	-3.09	.0020	-0.1202*	-3.09	.0020
02/87	-0.1025	-2.61	.0090	-0.1027	-2.61	.0090
04/87	-0.1014	-2.59	.0097	-0.1017	-2.59	.0096
06/87	-0.0976	-2.50	.0125	-0.0984	-2.52	.0119
08/87	-0.0928	-2.38	.0174	-0.0923	-2.36	.0182
10/87	-0.0890	-2.29	.0221	-0.0888	-2.28	.0227
12/87	-0.0896	-2.31	.0209	-0.0899	-2.31	.0207
02/88	-0.0953	-2.46	.0140	-0.0955	-2.46	.0139
04/88	-0.0925	-2.38	.0172	-0.0925	-2.38	.0175
06/88	-0.0961	-2.47	.0135	-0.0966	-2.48	.0132
08/88	-0.0930	-2.39	.0167	-0.0930	-2.39	.0169
10/88	-0.0896	-2.32	.0204	-0.0895	-2.31	.0208
12/88	-0.0726	-1.89	.0587	-0.0725	-1.89	.0594
02/89	-0.0592	-1.54	.1232	-0.0595	-1.55	.1222
04/89	-0.0387	-0.99	.3197	-0.0391	-1.00	.3165

TABLE 8. (CONT'D.).

VARIABLE	AMERICAN MODEL COEFFICIENT	AMERICAN MODEL T VALUE	AMERICAN MODEL P VALUE	EUROPEAN MODEL COEFFICIENT	EUROPEAN MODEL T VALUE	EUROPEAN MODEL P VALUE
SEASONAL DUMMIES						
JAN	-0.0129	-1.84	.0665	-0.0118	-1.83	.0670
FEB	-0.0079	-1.20	.2314	-0.0078	-1.18	.2387
MAR	-0.0048	-0.72	.4690	-0.0048	-0.71	.4764
APR	-0.0011	-0.16	.8748	-0.0005	-0.07	.9437
MAY	0.0010	0.14	.8854	0.0009	0.13	.8994
JUNE	-0.0053	-0.77	.4421	-0.0053	-0.78	.4374
JULY	-0.0220*	-3.29	.0010	-0.0219*	-3.26	.0011
AUG	-0.0223*	-3.14	.0009	-0.0225*	-3.34	.0008
SEPT	0.0210*	3.19	.0014	0.0206*	3.13	.0018
OCT	0.0112	1.70	.0895	0.0116	1.75	.0805
NOV	-0.0133	-1.99	.0460	-0.0133	-1.99	.0468
SUMMARY STATISTICS						
R^2	0.0403			0.0393		
ADJUSTED R^2	0.0364			0.0354		
F(REGRESSION)[d]	10.2290*			9.9760*		
p-value	(.0001)			(.0001)		
F(SEASONALITY)[e]	10.6851*			10.6165*		
p-value	(.0001)			(.0001)		
F(CONTRACT)[f]	5.3614			5.3346		
p-value	(.0001)			(.0001)		
OBSERVATIONS	10,274					

[a]The dependent variable is actual price - model price.
[b]TTM = time-to-maturity.
MONEYNESS = futures price/exercise price.
VOLATILITY = the historical volatility estimate.
INTEREST = riskless interest rate.
LIQUIDITY = difference in seconds between traded option and 11:00 a.m.
[c]* = Critical F- and t-values calculated according to Leamer (1978); t-value = 3.07 and F-value = 9.26.
[d]F(REGRESSION) = F-statistic to test hypothesis that coefficients on all variables are jointly insignificantly different from zero.
[e]F(SEASONALITY) = F-statistic to test hypothesis that coefficients on seasonal dummies are jointly insignificantly different from zero.
[f]F(CONTRACT) = F-statistic to test hypothesis that coefficients on contract dummies are jointly insignificantly different from zero.

TABLE 9. PRICING BIAS REGRESSIONS FOR LIVE CATTLE PUT OPTION PRICING MODELS: HISTORICAL VOLATILITY ESTIMATE.[a]

	AMERICAN MODEL			EUROPEAN MODEL		
VARIABLE[b]	COEF- FICIENT[c]	T VALUE	P VALUE	COEF- FICIENT	T VALUE	P VALUE
INTERCEPT	4.5375*	46.31	.0001	4.6003*	47.25	.0001
TTM	0.3659*	18.29	.0001	0.3964*	31.94	.0001
MONEYNESS	-1.1090*	-23.30	.0001	-1.1882*	-25.13	.0001
VOLATILITY	-5.4536*	-84.32	.0001	-5.4273*	-84.45	.0001
INTEREST	-9.6391*	-12.35	.0001	-9.4376*	-12.16	.0001
LIQUIDITY	-0.0001*	-9.00	.0001	-0.0001*	-8.79	.0001
CONTRACT DUMMIES						
02/85	-1.9431*	-24.97	.0001	-1.9459*	-25.17	.0001
04/85	-1.8158*	-26.31	.0001	-1.8203*	-26.55	.0001
06/85	-1.6914*	-25.12	.0001	-1.6943*	-25.33	.0001
08/85	-1.5970*	-24.03	.0001	-1.5997*	-24.22	.0001
10/85	-1.3980*	-20.98	.0001	-1.4020*	-21.18	.0001
12/85	-1.6658*	-25.16	.0001	-1.6679*	-25.35	.0001
02/86	-1.5579*	-23.52	.0001	-1.5605*	-23.71	.0001
04/86	-1.3398*	-20.15	.0001	-1.3429*	-20.32	.0001
06/86	-1.2225*	-18.39	.0001	-1.2242*	-18.53	.0001
08/86	-1.3011*	-19.47	.0001	-1.3018*	-19.60	.0001
10/86	-1.4285*	-21.33	.0001	-1.4285*	-21.47	.0001
12/86	-1.5552*	-23.25	.0001	-1.5547*	-23.39	.0001
02/87	-1.7025*	-25.31	.0001	-1.7032*	-25.48	.0001
04/87	-1.6512*	-24.66	.0001	-1.6517*	-24.82	.0001
06/87	-1.7436*	-26.13	.0001	-1.7438*	-26.30	.0001
08/87	-1.8153*	-27.24	.0001	-1.8155*	-27.42	.0001
10/87	-1.7390*	-26.19	.0001	-1.7397*	-26.23	.0001
12/87	-1.6296*	-24.70	.0001	-1.6315*	-24.88	.0001
02/88	-1.6280*	-24.64	.0001	-1.6291*	-24.81	.0001
04/88	-1.5772*	-23.82	.0001	-1.5764*	-23.96	.0001
06/88	-1.5342*	-23.17	.0001	-1.5328*	-23.29	.0001
08/88	-1.6015*	-24.27	.0001	-1.6016*	-24.42	.0001
10/88	-1.5065*	-22.98	.0001	-1.5079*	-23.14	.0001
12/88	-1.0428*	-15.92	.0001	-1.0437*	-16.04	.0001
02/89	-0.6108*	-9.22	.0001	-0.6115*	-9.29	.0001
04/89	-0.2903*	-4.24	.0001	-0.2898*	-4.26	.0001

TABLE 9. (CONT'D.).

VARIABLE	AMERICAN MODEL COEF-FICIENT	AMERICAN MODEL T VALUE	AMERICAN MODEL P VALUE	EUROPEAN MODEL COEF-FICIENT	EUROPEAN MODEL T VALUE	EUROPEAN MODEL P VALUE
SEASONAL DUMMIES						
JAN	-0.0274	-2.04	.0418	-0.0276	-2.06	.0391
FEB	-0.1337*	-9.56	.0001	-0.1332*	-9.58	.0001
MAR	-0.1703*	-12.06	.0001	-0.1702*	-12.13	.0001
APR	-0.1787*	-12.32	.0001	-0.1785*	-12.39	.0001
MAY	-0.1591*	-11.02	.0001	-0.1595*	-11.12	.0001
JUNE	-0.0270	-1.85	.0651	-0.0269	-1.85	.0647
JULY	-0.0615*	-4.27	.0001	-0.0617*	-4.31	.0001
AUG	-0.1961*	-13.70	.0001	-0.1959*	-13.77	.0001
SEPT	-0.1020*	-7.26	.0001	-0.1016*	-7.28	.0001
OCT	-0.0244	-1.77	.0771	-0.0230	-1.68	.0922
NOV	-0.0989*	-6.97	.0001	-0.0979*	-6.94	.0001
SUMMARY STATISTICS						
R^2	0.7332			0.7360		
ADJUSTED R^2	0.7320			0.7348		
F(REGRESSION)[d]	619.2470*			628.3590*		
p-value	(.0001)			(.0001)		
F(SEASONALITY)[e]	56.0943*			56.8028*		
p-value	(.0001)			(.0001)		
F(CONTRACT)[f]	379.0345*			384.6995*		
p-value	(.0001)			(.0001)		
OBSERVATIONS	9,508					

[a]The dependent variable is actual price - model price.
[b]TTM = time-to-maturity.
MONEYNESS = futures price/exercise price.
VOLATILITY = the historical volatility estimate.
INTEREST = riskless interest rate.
LIQUIDITY = difference in seconds between traded option and 11:00 a.m.
[c]* = Critical F- and t-values calculated according to Leamer (1978); t-value = 2.95 and F-value = 9.26
[d]F(REGRESSION) = F-statistic to test hypothesis that coefficients on all variables are jointly insignificantly different from zero.
[e]F(SEASONALITY) = F-statistic to test hypothesis that coefficients on seasonal dummies are jointly insignificantly different from zero.
[f]F(CONTRACT) = F-statistic to test hypothesis that coefficients on contract dummies are jointly insignificantly different from zero.

TABLE 10. PRICING BIASES FOR LIVE CATTLE PUT OPTION PRICING MODELS: AVERAGE IMPLIED VOLATILITY ESTIMATE.[b]

	AMERICAN MODEL			EUROPEAN MODEL		
VARIABLE[b]	COEF-FICIENT[c]	T VALUE	P VALUE	COEF-FICIENT	T VALUE	P VALUE
INTERCEPT	-0.5104*	-10.42	.0001	-0.4611*	-9.44	.0001
TTM	0.0705*	7.24	.0001	0.0745*	7.68	.0001
MONEYNESS	0.5289*	23.24	.0001	0.4743*	20.90	.0001
VOLATILITY	0.1201*	4.92	.0001	0.1213*	4.99	.0001
INTEREST	1.0439	2.82	.0048	1.1156*	3.02	.0025
LIQUIDITY	0.0001	1.63	.1038	0.0001	2.27	.0230
CONTRACT DUMMIES						
02/85	-0.0963	-2.49	.0127	-0.0983	-2.55	.0107
04/85	-0.1063*	-3.09	.0020	-0.1120*	-3.26	.0011
06/85	-0.1267*	-3.78	.0002	-0.1305*	-3.90	.0001
08/85	-0.1110*	-3.37	.0007	-0.1145*	-3.49	.0005
10/85	-0.1027*	-3.14	.0017	-0.1065*	-3.26	.0011
12/85	-0.1406*	-4.30	.0001	-0.1407*	-4.32	.0001
02/86	-0.1296*	-3.97	.0001	-0.1306*	-4.02	.0001
04/86	-0.1165*	-3.57	.0004	-0.1183*	-3.64	.0003
06/86	-0.1221*	-3.78	.0002	-0.1238*	-3.84	.0001
08/86	-0.1263*	-3.91	.0001	-0.1275*	-3.96	.0001
10/86	-0.1367*	-4.20	.0001	-0.1358*	-4.18	.0001
12/86	-0.1312*	-3.99	.0001	-0.1297*	-3.95	.0001
02/87	-0.1084*	-3.24	.0012	-0.1082*	-3.25	.0012
04/87	-0.1127*	-3.39	.0007	-0.1119*	-3.37	.0007
06/87	-0.1226*	-3.70	.0002	-0.1215*	-3.68	.0002
08/87	-0.1191*	-3.60	.0003	-0.1187*	-3.60	.0009
10/87	-0.1124*	-3.40	.0007	-0.1122*	-3.41	.0007
12/87	-0.1281*	-3.91	.0001	-0.1274*	-3.90	.0002
02/88	-0.1219*	-3.74	.0002	-0.1224*	-3.76	.0002
04/88	-0.1548*	-4.74	.0001	-0.1535*	-4.72	.0001
06/88	-0.1664*	-5.09	.0001	-0.1648*	-5.06	.0001
08/88	-0.1457*	-4.47	.0001	-0.1457*	-4.47	.0001
10/88	-0.1542*	-4.77	.0001	-0.1542*	-4.77	.0001
12/88	-0.1304*	-4.08	.0001	-0.1304*	-4.08	.0001
02/89	-0.1019*	-3.20	.0014	-0.1019*	-3.20	.0014
04/89	-0.0751	-2.29	.0220	-0.0751	-2.29	.0220

TABLE 10. (CONT'D.).

VARIABLE	AMERICAN MODEL COEF-FICIENT	T VALUE	P VALUE	EUROPEAN MODEL COEF-FICIENT	T VALUE	P VALUE
SEASONAL DUMMIES						
JAN	-0.0173	-2.69	.0072	-0.0165	-2.58	.0100
FEB	-0.0235*	-3.54	.0004	-0.0223*	-3.37	.0008
MAR	-0.0120	-1.78	.0750	-0.0118	-1.75	.0800
APR	-0.0041	-0.59	.5584	-0.0042	-0.61	.5402
MAY	-0.0017	-1.69	.0903	-0.0114	-1.65	.0990
JUNE	0.0076	1.09	.2771	0.0082	1.18	.2388
JULY	-0.0179	-2.64	.0083	-0.0179	-2.64	.0083
AUG	-0.0424*	-6.22	.0001	-0.0415*	-6.10	.0001
SEPT	0.0026	0.39	.7000	0.0025	0.37	.7113
OCT	-0.0152	-2.31	.0209	-0.0153	-2.32	.0202
NOV	-0.0176	-2.66	.0079	-0.0177	-2.67	.0076
SUMMARY STATISTICS						
R^2		0.0924			0.0924	
ADJUSTED R^2		0.0884			0.0884	
F(REGRESSION)[d]		22.9560*			22.9560*	
p-value		(.0001)			(.0001)	
F(SEASONALITY)[e]		10.5702*			10.5702*	
p-value		(.0001)			(.0001)	
F(CONTRACT)[f]		8.2257			8.2257	
p-value		(.0001)			(.0001)	
OBSERVATIONS		9,508				

[a]The dependent variable is actual price - model price.
[b]TTM = time-to-maturity.
MONEYNESS = futures price/exercise price.
VOLATILITY = the historical volatility estimate.
INTEREST = riskless interest rate.
LIQUIDITY = difference in seconds between traded option and 11:00 a.m.
[c]* = Critical F- and t-values calculated according to Leamer (1978); t-value = 2.95 and F-value = 9.26.
[d]F(REGRESSION) = F-statistic to test hypothesis that coefficients on all variables are jointly insignificantly different from zero.
[e]F(SEASONALITY) = F-statistic to test hypothesis that coefficients on seasonal dummies are jointly insignificantly different from zero.
[f]F(CONTRACT) = F-statistic to test hypothesis that coefficients on contract dummies are jointly insignificantly different from zero.

TABLE 11. PRICING BIAS REGRESSIONS FOR LIVE CATTLE PUT OPTION PRICING MODELS: AT-THE-MONEY IMPLIED VOLATILITY ESTIMATE.[a]

	AMERICAN MODEL			EUROPEAN MODEL		
VARIABLE[b]	COEF-FICIENT[c]	T VALUE	P VALUE	COEF-FICIENT	T VALUE	P VALUE
INTERCEPT	-0.3576*	-7.07	.0001	-0.2983*	-5.90	.0001
TTM	-0.0552*	-5.66	.0001	-0.0580*	-5.96	.0001
MONEYNESS	0.4357*	18.65	.0001	0.3784*	16.20	.0001
VOLATILITY	0.0348	1.31	.1905	0.0349	1.32	.1884
INTEREST	1.2121*	3.19	.0014	1.2128*	3.19	.0014
LIQUIDITY	-0.0001	-0.57	.5684	-0.0001	-0.09	.9249
CONTRACT DUMMIES						
02/85	-0.1614*	-4.05	.0001	-0.1631*	-4.10	.0001
04/85	-0.1659*	-4.66	.0001	-0.1680*	-4.73	.0001
06/85	-0.1552*	-4.47	.0001	-0.1564*	-4.51	.0001
08/85	-0.1339*	-3.94	.0001	-0.1349*	-3.97	.0001
10/85	-0.1243*	-3.68	.0002	-0.1249*	-3.70	.0002
12/85	-0.1432*	-4.24	.0001	-0.1439*	-4.27	.0001
02/86	-0.1434*	-4.26	.0001	-0.1449*	-4.30	.0001
04/86	-0.1492*	-4.44	.0001	-0.1508*	-4.49	.0001
06/86	-0.1657*	-4.98	.0001	-0.1662*	-5.00	.0001
08/86	-0.1656*	-4.98	.0001	-0.1658*	-4.98	.0001
10/86	-0.1659*	-4.95	.0001	-0.1661*	-4.95	.0001
12/86	-0.1546*	-4.55	.0001	-0.1553*	-4.57	.0001
02/87	-0.1356*	-3.93	.0001	-0.1373*	-3.98	.0001
04/87	-0.1449*	-4.22	.0001	-0.1459*	-4.25	.0001
06/87	-0.1474*	-4.31	.0001	-0.1488*	-4.35	.0001
08/87	-0.1404*	-4.10	.0001	-0.1414*	-4.14	.0001
10/87	-0.1340*	-3.93	.0001	-0.1346*	-3.95	.0001
12/87	-0.1436*	-4.25	.0001	-0.1442*	-4.26	.0001
02/88	-0.1369*	-4.06	.0001	-0.1371*	-4.07	.0001
04/88	-0.1344*	-3.99	.0001	-0.1353*	-4.01	.0001
06/88	-0.1225*	-3.63	.0003	-0.1226*	-3.63	.0003
08/88	-0.1151*	-3.41	.0007	-0.1162*	-3.44	.0006
10/88	-0.1109*	-3.31	.0009	-0.1116*	-3.33	.0009
12/88	-0.0972	-2.94	.0033	-0.0980*	-2.97	.0030
02/89	-0.0830	-2.52	.0117	-0.0831	-2.53	.0115
04/89	-0.0479	-1.42	.1562	-0.0473	-1.40	.1612

TABLE 11. (CONT'D.).

	AMERICAN MODEL			EUROPEAN MODEL		
VARIABLE	COEF-FICIENT	T VALUE	P VALUE	COEF-FICIENT	T VALUE	P VALUE
SEASONAL DUMMIES						
JAN	0.0120	1.82	.0690	0.0121	1.84	.0655
FEB	0.0166	2.42	.0154	0.0169	2.48	.0131
MAR	0.0129	1.85	.0641	0.0125	1.80	.0719
APR	0.0119	1.67	.0941	0.0123	1.73	.0845
MAY	0.0148	2.08	.0377	0.0150	2.11	.0346
JUNE	0.0118	1.65	.1000	0.0119	1.66	.0980
JULY	-0.0118	-1.69	.0903	-0.0119	-1.71	.0865
AUG	-0.0135	-1.92	.0550	-0.0135	-1.92	.0551
SEPT	0.0217*	3.13	.0017	0.0212*	3.07	.0022
OCT	-0.0133	-1.97	.0494	-0.0129	1.91	.0568
NOV	-0.0052	-0.76	.4472	-0.0049	-0.72	.4700
SUMMARY STATISTICS						
R^2		0.1006			0.0924	
ADJUSTED R^2		0.0966			0.0884	
F(REGRESSION)[d]		25.2160*			22.9450*	
p-value		(.0001)			(.0001)	
F(SEASONALITY)[e]		8.0787			8.0044	
p-value		(.0001)			(.0001)	
F(CONTRACT)[f]		10.7817*			10.8439*	
p-value		(.0001)			(.0001)	
OBSERVATIONS		9,508				

[a]The dependent variable is actual price - model price.
[b]TTM = time-to-maturity.
MONEYNESS = futures price/exercise price.
VOLATILITY = the historical volatility estimate.
INTEREST = riskless interest rate.
LIQUIDITY = difference in seconds between traded option and 11:00 a.m.
[c]* = Critical F- and t-values calculated according to Leamer (1978); t-value = 2.95 and F-value = 9.26.
[d]F(REGRESSION) = F-statistic to test hypothesis that coefficients on all variables are jointly insignificantly different from zero.
[e]F(SEASONALITY) = F-statistic to test hypothesis that coefficients on seasonal dummies are jointly insignificantly different from zero.
[f]F(CONTRACT) = F-statistic to test hypothesis that coefficients on contract dummies are jointly insignificantly different from zero.

TABLE 12. PRICING BIAS REGRESSIONS FOR LIVE CATTLE PUT OPTION PRICING MODELS: STRIKE PRICE MATCHED IMPLIED VOLATILITY ESTIMATE.[a]

	AMERICAN MODEL			EUROPEAN MODEL		
VARIABLE[b]	COEF-FICIENT[c]	T VALUE	P VALUE	COEF-FICIENT	T VALUE	P VALUE
INTERCEPT	-0.0787	-1.33	.1826	-0.0546	-0.92	.3556
TTM	0.0022	0.19	.8507	0.0045	0.39	.7003
MONEYNESS	0.1005*	3.61	.0003	0.0759	2.73	.0064
VOLATILITY	0.0206	0.71	.4755	0.0210	0.73	.4646
INTEREST	1.9257*	4.26	.0001	1.9372*	4.29	.0001
LIQUIDITY	0.0001	1.52	.1288	0.0001	1.69	.0910
CONTRACT DUMMIES						
02/85	-0.1653*	-3.51	.0005	-0.1654*	-3.51	.0004
04/85	-0.1760*	-4.20	.0001	-0.1763*	-4.21	.0001
06/85	-0.1824*	-4.46	.0001	-0.1828*	-4.47	.0001
08/85	-0.1789*	-4.46	.0001	-0.1789*	-4.46	.0001
10/85	-0.1351*	-3.38	.0007	-0.1348*	-3.38	.0007
12/85	-0.1550*	-3.89	.0001	-0.1544*	-3.87	.0001
02/86	-0.1529*	-3.84	.0001	-0.1534*	-3.86	.0001
04/86	-0.1546*	-3.89	.0001	-0.1548*	-3.89	.0001
06/86	-0.1514*	-3.91	.0001	-0.1540*	-3.91	.0001
08/86	-0.1522*	-3.86	.0001	-0.1520*	-3.85	.0001
10/86	-0.1420*	-3.57	.0004	-0.1416*	-3.57	.0004
12/86	-0.1378*	-3.43	.0006	-0.1377*	-3.43	.0006
02/87	-0.1260*	-3.09	.0020	-0.1262*	-3.10	.0020
04/87	-0.1324*	-3.26	.0011	-0.1321*	-3.26	.0011
06/87	-0.1382*	-3.42	.0006	-0.1382*	-3.42	.0006
08/87	-0.1371*	-3.39	.0007	-0.1369*	-3.39	.0007
10/87	-0.1260*	-3.13	.0018	-0.1261*	-3.13	.0017
12/87	-0.1373*	-3.44	.0006	-0.1371*	-3.43	.0006
02/88	-0.1346*	-3.38	.0007	-0.1347*	-3.38	.0007
04/88	-0.1399*	-3.51	.0004	-0.1393*	-3.50	.0005
06/88	-0.1485*	-3.72	.0002	-0.1480*	-3.71	.0002
08/88	-0.1509*	-3.78	.0002	-0.1509*	-3.79	.0002
10/88	-0.1408*	-3.56	.0004	-0.1406*	-3.56	.0004
12/88	-0.1262*	-3.23	.0013	-0.1259*	-3.22	.0013
02/89	-0.0934	-2.39	.0169	-0.0934	-2.39	.0169
04/89	-0.0507	-1.26	.2075	-0.0502	-1.25	.2118

TABLE 12. (CONT'D.).

VARIABLE	AMERICAN MODEL COEF-FICIENT	T VALUE	P VALUE	EUROPEAN MODEL COEF-FICIENT	T VALUE	P VALUE
SEASONAL DUMMIES						
JAN	0.0046	0.58	.5606	0.0044	0.55	.5798
FEB	0.0083	1.02	.3068	0.0083	1.02	.3076
MAR	0.0109	1.32	.1879	0.0106	1.28	.2002
APR	0.0106	1.25	.2103	0.0105	1.23	.2178
MAY	0.0104	1.23	.2176	0.0104	1.24	.2167
JUNE	0.0129	1.50	.1331	0.0129	1.51	.1320
JULY	-0.0132	-1.60	.1108	-0.0134	-1.62	.1050
AUG	-0.0271*	-3.26	.0011	-0.0270*	-3.25	.0012
SEPT	0.0144	1.74	.0814	0.0142	1.73	.0846
OCT	-0.0122	-1.52	.1295	-0.0126	-1.57	.1175
NOV	-0.0060	0.73	.4630	-0.0059	-0.73	.4646
SUMMARY STATISTICS						
R^2	0.0278			0.0271		
ADJUSTED R^2	0.0234			0.0228		
F(REGRESSION)[d]	6.4340			6.2850		
p-value	(.0001)			(.0001)		
F(SEASONALITY)[e]	6.1292			6.1239		
p-value	(.0001)			(.0001)		
F(CONTRACT)[f]	3.7682			3.7795		
p-value	(.0001)			(.0001)		
OBSERVATIONS	9,508					

[a]The dependent variable is actual price - model price.
[b]TTM = time-to-maturity.
MONEYNESS = futures price/exercise price.
VOLATILITY = the historical volatility estimate.
INTEREST = riskless interest rate.
LIQUIDITY = difference in seconds between traded option and 11:00 a.m.
[c]* = Critical F- and t-values calculated according to Leamer (1978); t-value = 2.95 and F-value = 9.26.
[d]F(REGRESSION) = F-statistic to test hypothesis that coefficients on all variables are jointly insignificantly different from zero.
[e]F(SEASONALITY) = F-statistic to test hypothesis that coefficients on seasonal dummies are jointly insignificantly different from zero.
[f]F(CONTRACT) = F-statistic to test hypothesis that coefficients on contract dummies are jointly insignificantly different from zero.

TABLE 13. PRICING BIAS REGRESSIONS FOR FEEDER CATTLE OPTION PRICING MODELS: HISTORICAL VOLATILITY ESTIMATE.[a]

	AMERICAN MODEL			EUROPEAN MODEL		
VARIABLE[b]	COEF-FICIENT[c]	T VALUE	P VALUE	COEF-FICIENT	T VALUE	P VALUE
CALLS (OBS = 868):						
INTERCEPT	-0.3595	-0.81	.4169	-0.4951	-1.12	.2636
TTM	1.3375*	8.23	.0001	1.3717*	8.45	.0001
MONEYNESS	0.2693	0.71	.4754	0.3968	1.05	.2930
VOLATILITY	-8.3189*	-23.11	.0001	-8.3003*	-23.06	.0001
INTEREST	21.6856*	7.26	.0001	21.7736*	7.29	.0001
LIQUIDITY	0.0001	0.89	.3756	0.0001	0.90	.3676
SUMMARY STATISTICS						
R^2		0.4226			0.4225	
ADJUSTED R^2		0.4192			0.4192	
F(REGRESSION)[d]		126.3160*			126.2860*	
p-value		(.0001)			(.0001)	
PUTS (OBS = 1,171):						
INTERCEPT	0.0598	0.19	.8482	0.1149	0.37	.7125
TTM	1.2900*	11.02	.0001	1.3159*	11.24	.0001
MONEYNESS	-0.2182	-0.87	.3837	-0.2796	-1.12	.2643
VOLATILITY	-8.8833*	-29.76	.0001	-8.8584*	-29.69	.0001
INTEREST	26.4460*	10.76	.0001	26.5026*	10.79	.0001
LIQUIDITY	-0.0001	-1.76	.0793	-0.0001	-1.76	.0780
SUMMARY STATISTICS						
R^2		0.4894			0.4899	
ADJUSTED R^2		0.4872			0.4877	
F(REGRESSION)[d]		223.5290*			223.9480*	
p-value		(.0001)			(.0001)	

[a]The dependent variable is actual price - model price in units.
[b]TTM = time-to-maturity.
MONEYNESS = futures price/exercise price.
INTEREST = riskless interest rate.
VOLATILITY = historical volatility estimate.
LIQUIDITY = difference in seconds between traded option and 11:00 a.m.
[c]* = Critical F- and t-values calculated according to Leamer (1978); t-value for call (put) = 2.65 (2.73) and F-value = 6.87 (7.12).
[d]F(REGRESSION) = F-statistic to test hypothesis that coefficients on all variables are jointly insignificantly different from zero.

TABLE 14. PRICING BIAS REGRESSIONS FOR FEEDER CATTLE OPTION PRICING MODELS: AVERAGE IMPLIED VOLATILITY ESTIMATE.[a]

	AMERICAN MODEL			EUROPEAN MODEL		
VARIABLE[b]	COEF-FICIENT[c]	T VALUE	P VALUE	COEF-FICIENT	T VALUE	P VALUE
CALLS (OBS = 868):						
INTERCEPT	-0.4997	-2.55	.0109	-0.5997*	-3.05	.0024
TTM	0.2068*	2.87	.0042	0.2323*	3.21	.0014
MONEYNESS	0.3401	2.03	.0431	0.4294	2.55	.0111
VOLATILITY	0.2041	2.13	.0331	0.2069	2.15	.0319
INTEREST	1.1019	0.81	.4183	1.1919	0.87	.3837
LIQUIDITY	0.0001	2.20	.0281	0.0001	2.27	.0235
SUMMARY STATISTICS						
R^2		0.0213			0.0251	
ADJUSTED R^2		0.0157			0.0194	
F(REGRESSION)[d]		3.7620			4.4360	
p-value		(.0024)			(.0006)	
PUTS (OBS = 1,171):						
INTERCEPT	-1.5127*	-10.80	.0001	-1.4717*	-10.60	.0001
TTM	0.0698	1.35	.1787	0.0754	1.47	.1436
MONEYNESS	1.2801*	11.42	.0001	1.2424*	11.19	.0001
VOLATILITY	0.2690*	4.09	.0001	0.2781*	4.27	.0001
INTEREST	1.7320	1.52	.1294	1.6530	1.46	.1444
LIQUIDITY	-0.0001	-1.54	.1229	0.0001	-1.53	.1255
SUMMARY STATISTICS						
R^2		0.1297			0.1274	
ADJUSTED R^2		0.1260			0.1237	
F(REGRESSION)[d]		34.7500*			34.0610*	
p-value		(.0001)			(.0001)	

[a]The dependent variable is actual price - model price in units.
[b]TTM = time-to-maturity.
MONEYNESS = futures price/exercise price.
INTEREST = riskless interest rate.
VOLATILITY = historical volatility estimate.
LIQUIDITY = difference in seconds between traded option and 11:00 a.m.
[c]* = Critical F- and t-values calculated according to Leamer (1978); t-value for call (put) = 2.65 (2.73) and F-value = 6.87 (7.12).
[d]F(REGRESSION) = F-statistic to test hypothesis that coefficients on all variables are jointly insignificantly different from zero.

TABLE 15. PRICING BIAS REGRESSIONS FOR FEEDER CATTLE OPTION PRICING MODELS: AT-THE-MONEY IMPLIED VOLATILITY ESTIMATE.[a]

VARIABLE[b]	AMERICAN MODEL COEFFICIENT[c]	AMERICAN MODEL T VALUE	AMERICAN MODEL P VALUE	EUROPEAN MODEL COEFFICIENT	EUROPEAN MODEL T VALUE	EUROPEAN MODEL P VALUE
CALLS (OBS = 868):						
INTERCEPT	-0.2103	-1.03	.3031	-0.3169	-1.54	.1219
TTM	0.0185	0.25	.8054	0.0292	0.39	.6970
MONEYNESS	0.1708	0.98	.3293	0.2765	1.58	.1155
VOLATILITY	0.0091	0.09	.9256	0.0113	0.12	.9076
INTEREST	0.2527	0.18	.8594	0.2652	0.19	.8529
LIQUIDITY	0.0001	2.12	.0340	0.0001	2.16	.0308
SUMMARY STATISTICS						
R^2		0.0067			0.0089	
ADJUSTED R^2		0.0009			0.0031	
F(REGRESSION)[d]		1.1630			1.5420	
p-value		(.3255)			(.1730)	
PUTS (1,171):						
INTERCEPT	-1.1619*	-8.43	.0001	-1.1174*	-8.14	.0001
TTM	-0.0169	-0.33	.7393	-0.0199	-0.39	.6946
MONEYNESS	1.0994*	9.98	.0001	1.0564*	9.64	.0001
VOLATILITY	0.2185*	3.40	.0007	0.2208*	3.46	.0006
INTEREST	0.6274	0.56	.5773	0.6274	0.56	.5755
LIQUIDITY	-0.0001	-2.53	.0115	-0.0001	-2.56	.0108
SUMMARY STATISTICS						
R^2		0.1001			0.0956	
ADJUSTED R^2		0.0962			0.0917	
F(REGRESSION)[d]		25.9280*			24.6570*	
p-value		(.0001)			(.0001)	

[a]The dependent variable is actual price - model price in units.
[b]TTM = time-to-maturity.
MONEYNESS = futures price/exercise price.
INTEREST = riskless interest rate.
VOLATILITY = historical volatility estimate.
LIQUIDITY = difference in seconds between traded option and 11:00 a.m.
[c]* = Critical F- and t-values calculated according to Leamer (1978); t-value for call (put) = 2.65 (2.73) and F-value 6.87 (7.12).
[d]F(REGRESSION) = F-statistic to test hypothesis that coefficients on all variables are jointly insignificantly different from zero.

TABLE 16. PRICING BIAS REGRESSIONS FOR FEEDER CATTLE OPTION PRICING MODELS: STRIKE PRICE MATCHED IMPLIED VOLATILITY ESTIMATE.[a]

	AMERICAN MODEL			EUROPEAN MODEL		
VARIABLE[b]	COEF-FICIENT[c]	T VALUE	P VALUE	COEF-FICIENT	T VALUE	P VALUE
CALLS (OBS = 868):						
INTERCEPT	-0.0056	-0.27	.7843	-0.1149	-0.56	.5731
TTM	0.0666	0.89	.3732	0.0778	1.04	.2992
MONEYNESS	0.0107	0.06	.9510	0.0703	0.40	.6865
VOLATILITY	-0.0192	-0.20	.8419	-0.0204	-0.21	.8323
INTEREST	0.2959	0.21	.8345	0.2753	0.19	.8462
LIQUIDITY	0.0001	2.37	.0180	0.0001	2.43	.0153
SUMMARY STATISTICS						
R^2		0.0078			0.0086	
ADJUSTED R^2		0.0021			0.0028	
F(REGRESSION)[d]		1.3610			1.4930	
p-value		(.2357)			(.1884)	
PUTS (OBS = 1,171):						
INTERCEPT	-0.6221*	-4.37	.0001	-0.5977*	-4.22	.0001
TTM	0.0316	0.61	.5443	0.0349	0.67	.5005
MONEYNESS	0.4915*	4.32	.0001	0.4694*	4.15	.0001
VOLATILITY	0.2423*	3.67	.0003	0.2460*	3.74	.0002
INTEREST	1.3692	1.19	.2330	1.3298	1.16	.2453
LIQUIDITY	-0.0001	-2.56	.0107	-0.0001	-2.57	.0103
SUMMARY STATISTICS						
R^2		0.0428			0.0420	
ADJUSTED R^2		0.0387			0.0379	
F(REGRESSION)[d]		10.4320*			10.2240*	
p-value		(.0001)			(.0001)	

[a]The dependent variable is actual price - model price in units.
[b]TTM = time-to-maturity.
MONEYNESS = futures price/exercise price.
INTEREST = riskless interest rate.
VOLATILITY = historical volatility estimate.
LIQUIDITY = difference in seconds between traded option and 11:00 a.m.
[c]* = Critical F- and t-values calculated according to Leamer (1978); t-value for call (put) = 2.65 (7.12) and F-value = 6.87 (7.12).
[d]F(REGRESSION) = F-statistic to test hypothesis that coefficients on all variables are jointly insignificantly different from zero.

Figure 1. Time-to-Maturity Pricing Bias: European Model, Live Cattle Calls

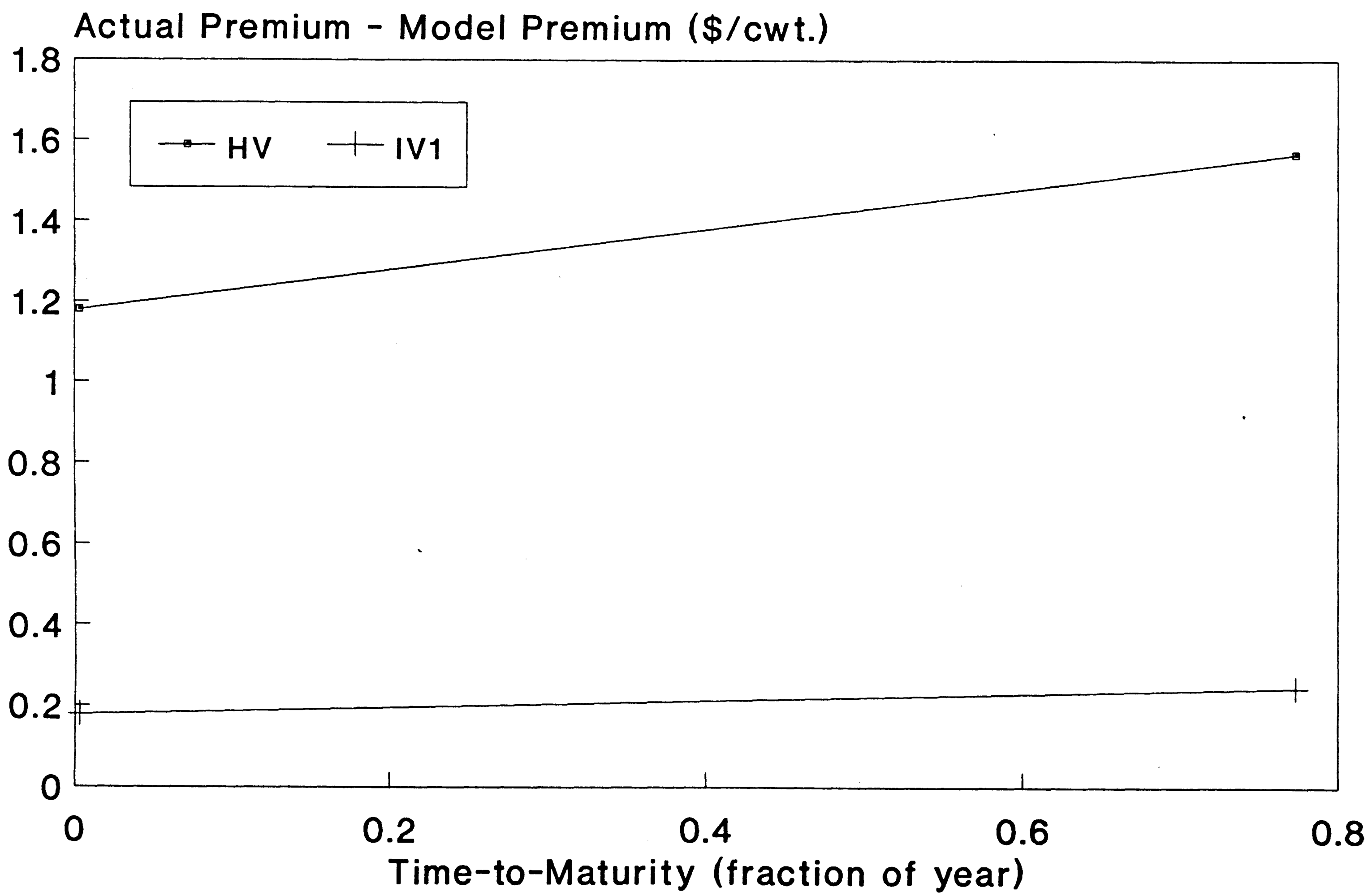

Figure 2. Time-to-Maturity Pricing Bias: European Model, Live Cattle Puts

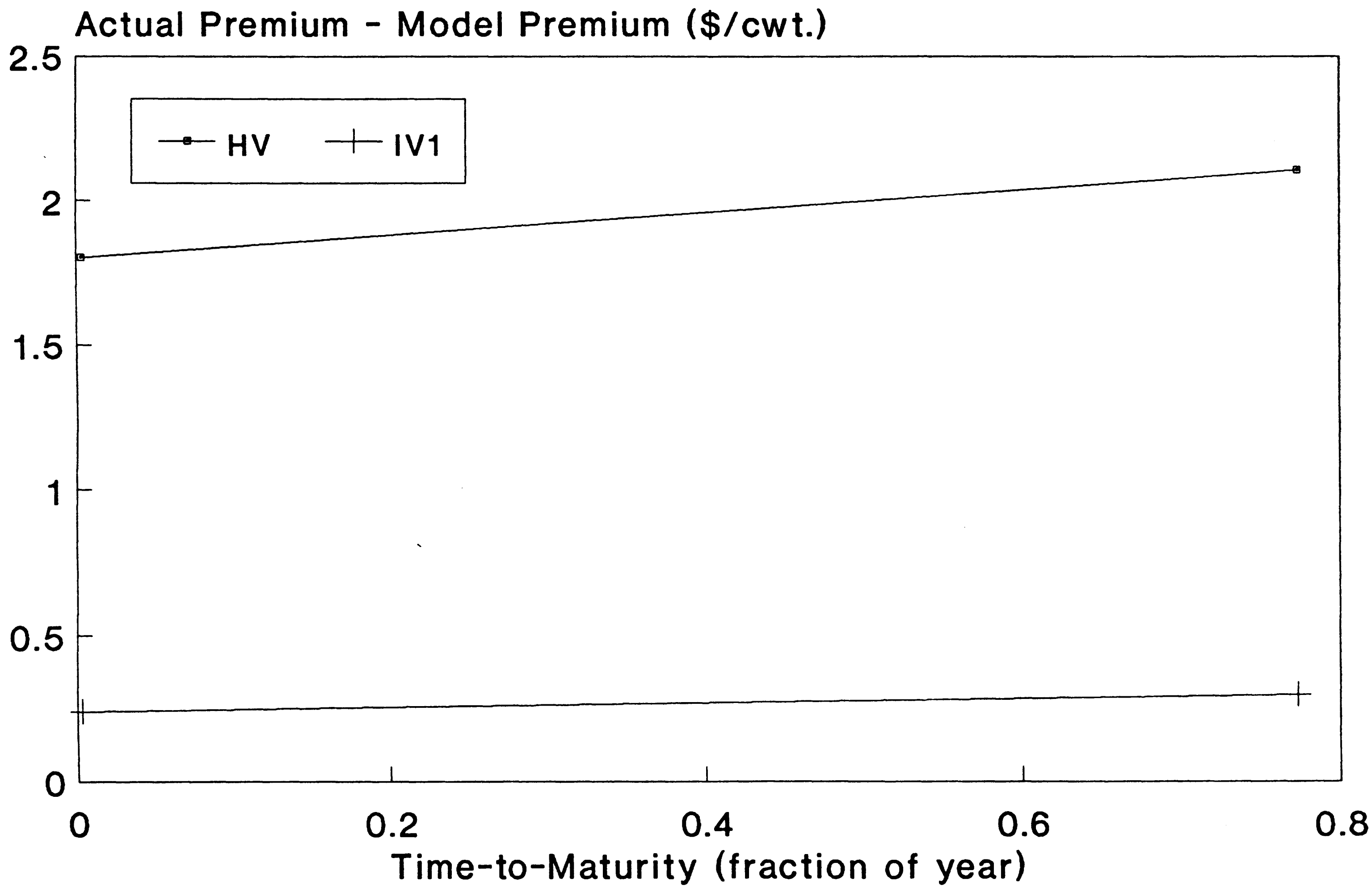

Figure 3. Time-to-Maturity Pricing Bias
European Model, Feeder Cattle Calls

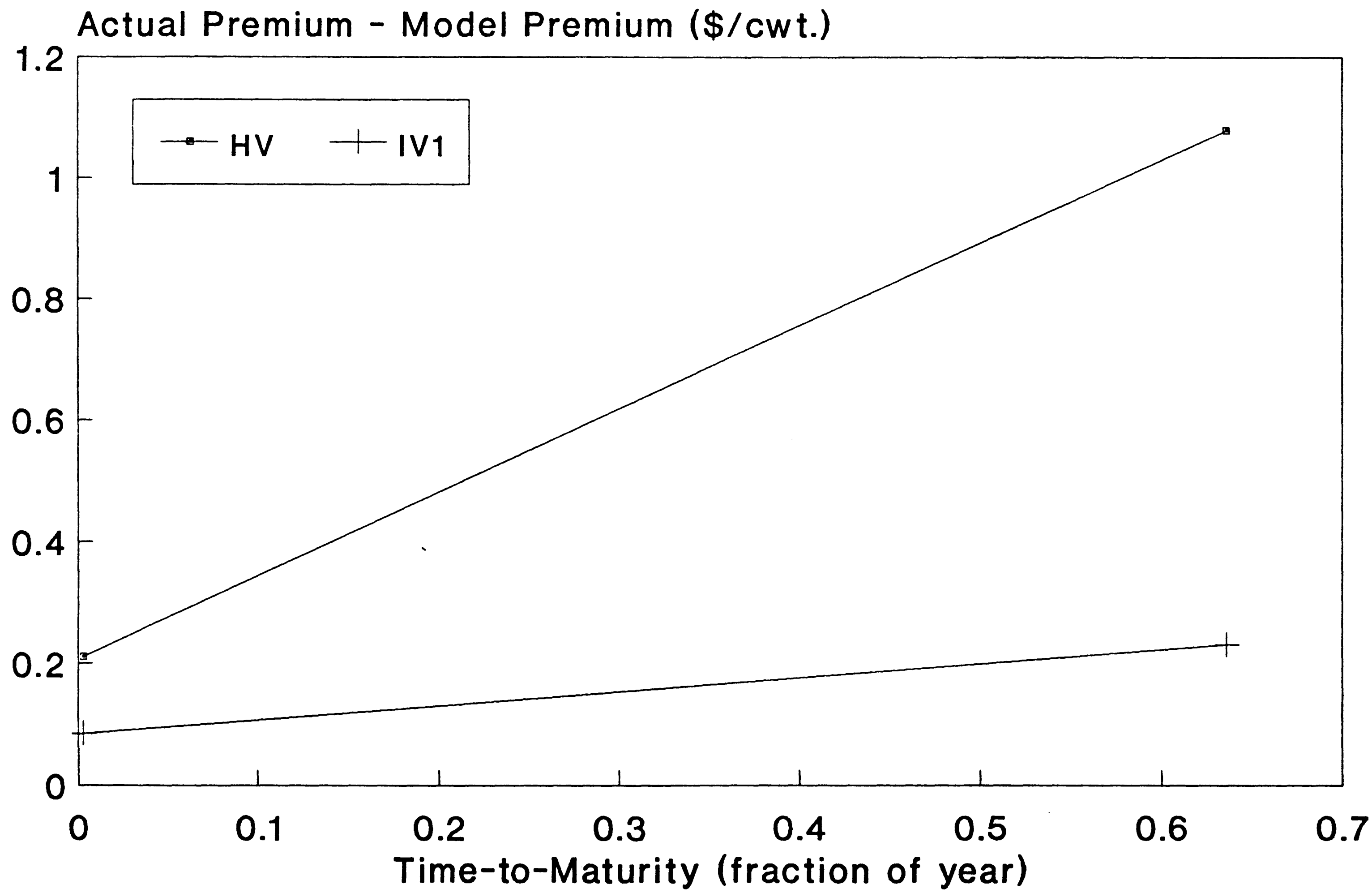

Figure 4. Volatility Pricing Bias: European Model, Live Cattle Calls

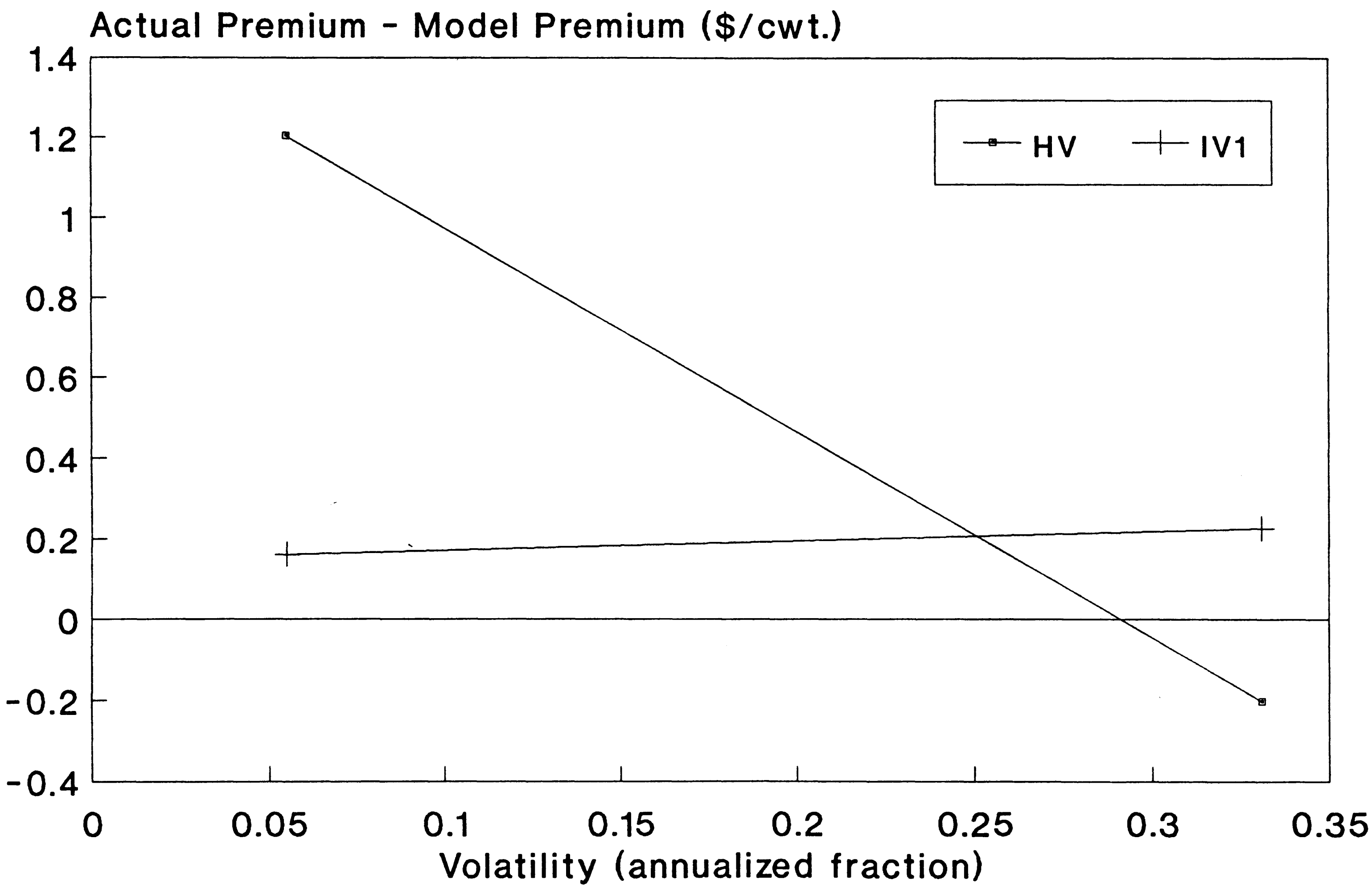

Figure 5. Volatility Pricing Bias: European Model, Live Cattle Puts

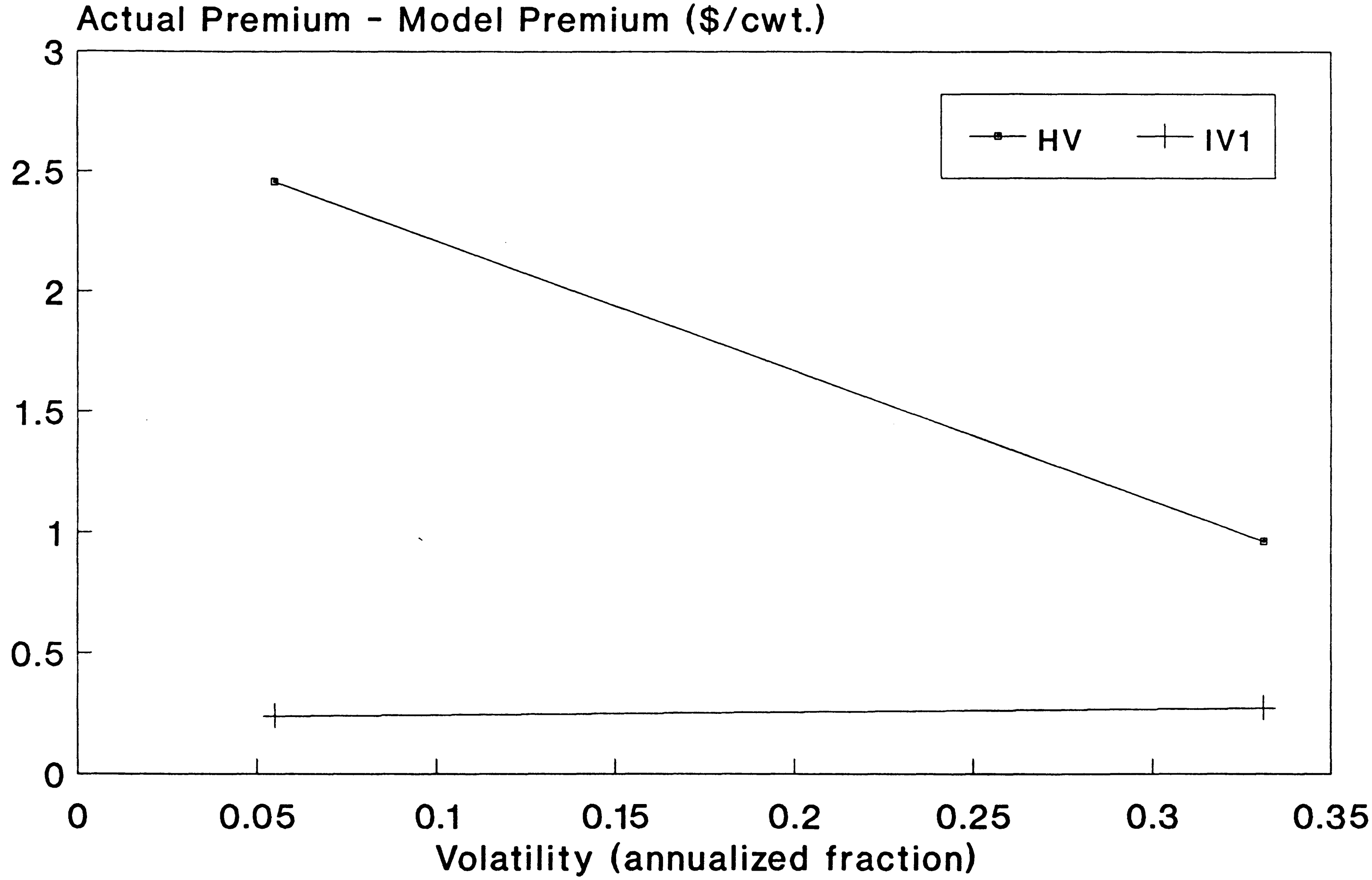

Figure 6. Volatility Pricing Bias: European Model, Feeder Cattle Puts

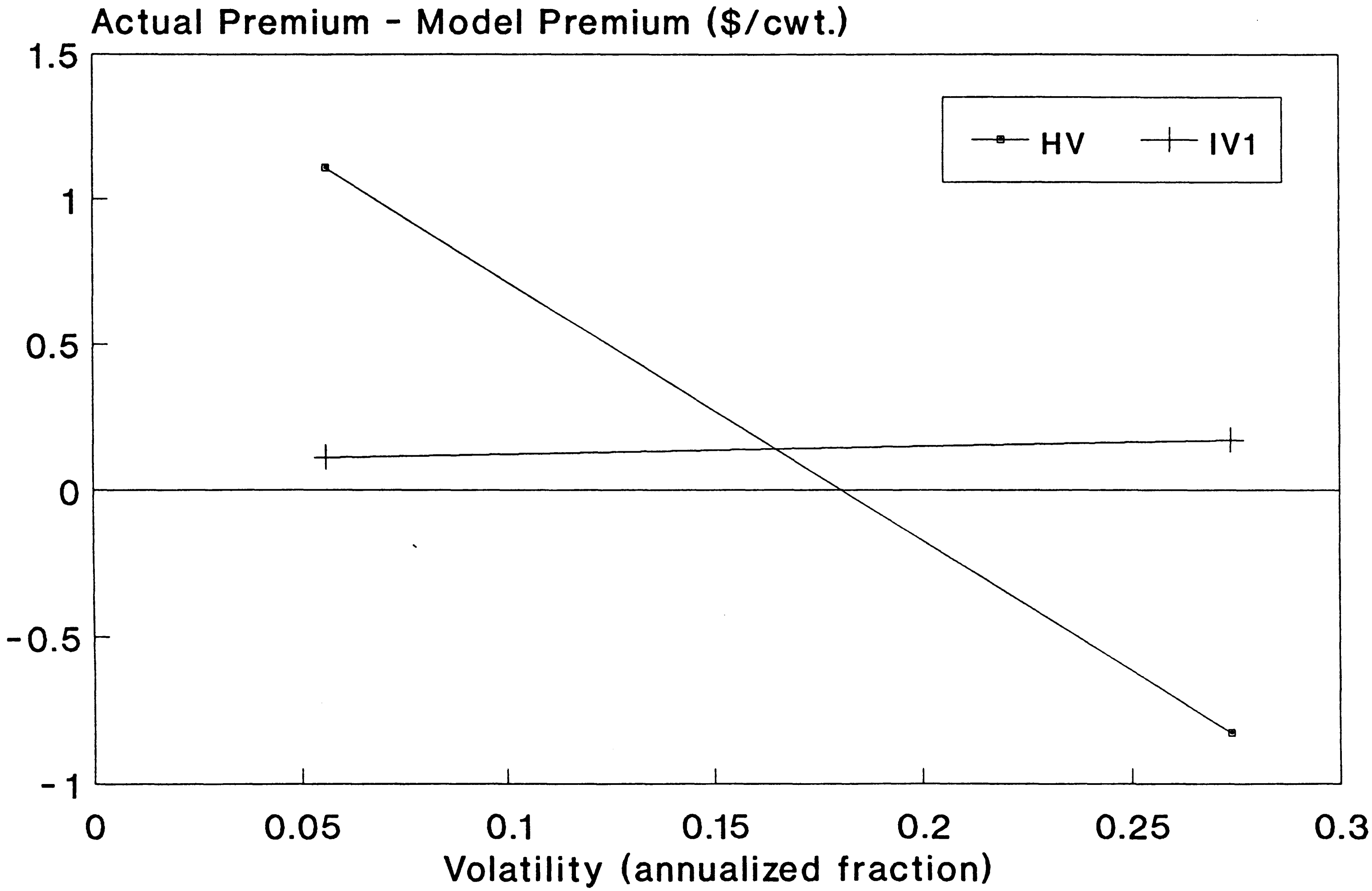

Figure 7. Moneyness Pricing Bias: European Model, Live Cattle Puts

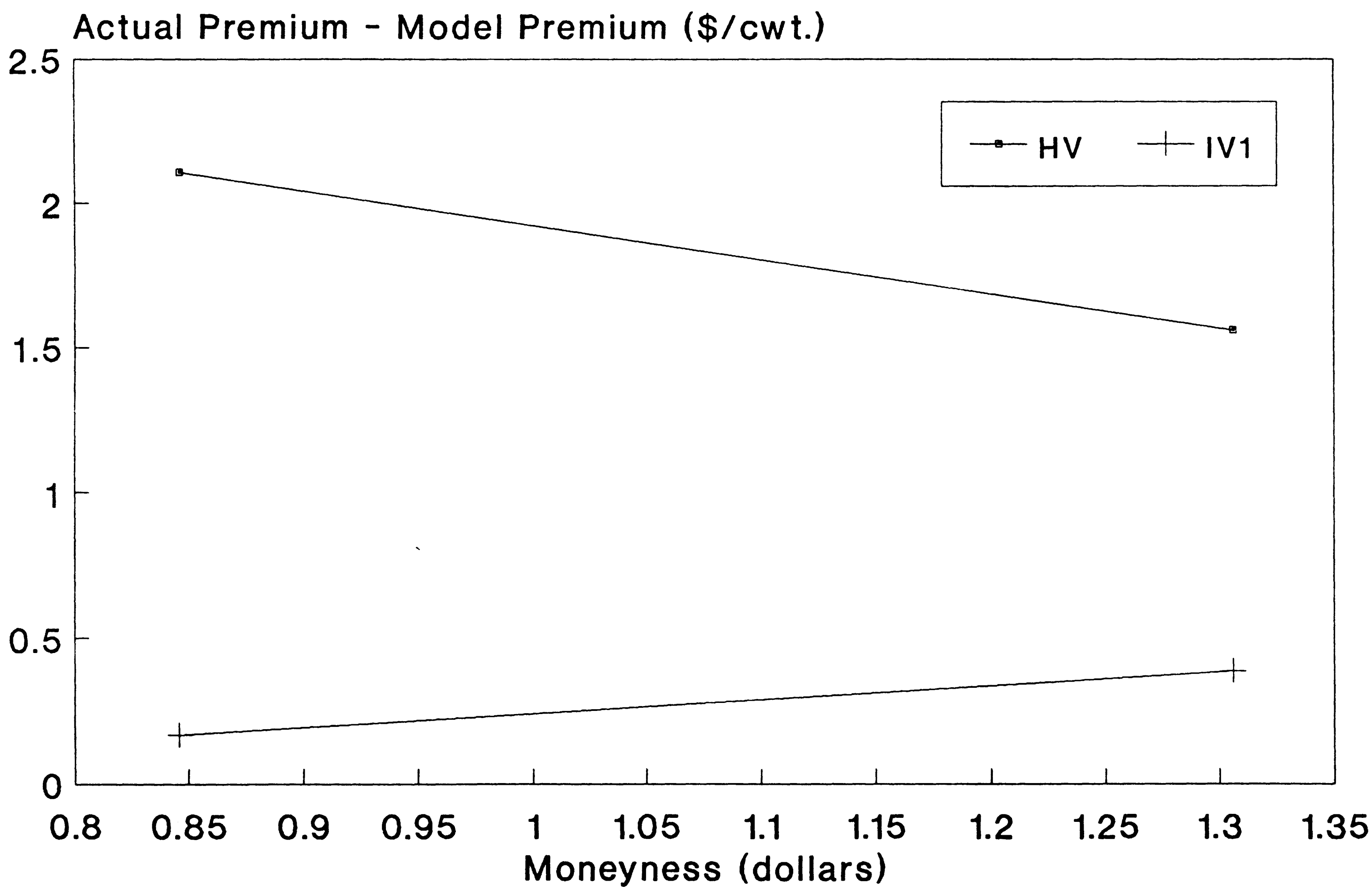

Figure 8. Interest Rate Pricing Bias: European Model, Live Cattle Puts